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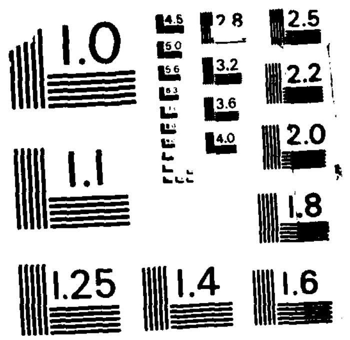

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

ARCHITECT/ENGINEER LIABILITY
IN CONSTRUCTION CONTRACTING

by

Mark Ernest Maynard

December 1986

Thesis Advisor: James M. Fremgen

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Architect/Engineer Liability in Construction Contracting

by

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Lieutenant, Civil Engineer Corps, United States Navy
B.S.C.E., University of Washington, 1978

Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

This thesis investigates possible relationships between the amount of Architect/Engineer firm (A/E) liability and A/E costs and/or construction costs. A/E's provide plans and specifications for Government construction projects. Any changes which occur during the course of construction can lead to A/E liability when the corrective work includes unproductive costs. The data for this thesis includes the A/E design costs, construction costs, and the amount of A/E liability for each project. The projects were classified as not complex, complex, and very complex based on the construction characteristics of each project. Regression analysis was used in the search for a predictive mathematical equation. The best equation explained only 29.0% of the variation in A/E liability. Consequently, this study did not establish any significant relationship between the amount of A/E liability and A/E costs and/or construction costs. The background research did indicate that the A/E should have a much greater involvement in a project during construction. It is recommended that the project A/E be required to make site visits at least weekly.

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I. INTRODUCTION TO ARCHITECT/ENGINEER LIABILITY

A. INTRODUCTION

The Government has tasked the military construction project manager with the duty of documenting design deficiencies and attempting to recover the additional costs incurred as a result of the design deficiency. Errors or omissions in the design lead to additional costs to the Government in the form of change orders to the construction contract. When these design deficiencies result from negligence on the part of the designer, the Architect/Engineer firm (A/E) that designed the project for the Government may be liable for these additional costs. Historically, there has been little or no sucess in recovery of these costs from the A/E.

This study was done with the underlying purpose of finding ways of improving the recovery of these A/E liability costs and minimizing the number of design errors. If a manager could predict the incidence and amount of A/E liabilit on future contracts, then the manager could place more emphasis on minimizing the damages to all parties. As the Government successfully pursues A/E liability, the A/Es will improve their design work and eliminate many of the design deficiencies. Fewer

deficiencies mean less management effort in handling construction change orders; in other words, a "win -win" situation. Data from over one hundred construction projects from 1976 to 1984 were evaluated and analyzed through regression analysis. No usable mathematical equation was found to predict the amount of A/E liability on future projects. However, the results indicated a higher chance of A/E liability occurrence in very complex projects.

The background of A/E liability and its evolution are contained in Chapter II. The origins of the data for this thesis and the method of research are presented in Chapter III. The steps used in the search for a mathematical model predicting the amount of A/E liability are described in Chapter IV. Finally, the conclusions and recommendations are contained in Chapter V.

II. WHAT IS ARCHITECT/ENGINEER LIABILITY?

A. INTRODUCTION

A/Es provide plans and specifications for construction projects. These plans and specifications are then advertized and awarded to a construction contractor. During the course of construction, changes to the plans and specifications involving design errors or omissions can lead to A/E liability. The corrective work to the design problem may involve paying the construction contractor for unproductive costs. (Unproductive costs are those costs which add no value to the construction project.) The costs may include rework, impact, or extended overhead costs. Rework takes place when the correction to the design requires work-in-place to be removed and then replaced in a different configuration. The construction contractor receives additional compensation for this rework, but no additional value is added to the project. Impact costs relate to additional moves within a job, set-backs in the learning curve of the craftsmen who have been pulled off a job while awaiting the design change, come-backs or return trips by specialty trades, and crew size inefficiency. A design change during construction can affect the efficiency of the construction contractor's

scheduling. The resulting impact costs add to the project's cost, but do not add value. Extended overhead costs of the construction contractor include the overhead costs (field office, equipment, personnel, etc.) of staying mobilized longer than originally planned. The Critical Path Method (CPM) of scheduling is typically used on construction contracts. The CPM can prove that a corrective design extended the critical path and caused the construction contractor to stay mobilized longer than planned. The A/E is justly responsible for these unproductive costs.

B. PRIVITY OF CONTRACT

An owner of property contracts with an A/E for design services and then contracts with a construction contractor to complete the work identified on the plans and specifications. There typically has been no contractual arrangement between the construction contractor and the A/E. Parties to a contract have a legal right to sue each other for nonperformance if necessary. This right is a consequence of privity of contract, which means that there is a direct and immediate legal relationship between the parties to a contract. The construction contractor could not sue the A/E for damages resulting from an improper set of plans and specifications, because there was no legal contract between the A/E and the construction contractor. By the late 1950's the courts began to reevaluate this premise.

The Federal Courts in a California district ruled on a case in 1958. The construction contractor placed defective concrete in a Government building project, and the concrete subsequently had to be removed and replaced. The Government contracted with the A/E for the design of the building and supervision during construction. The construction contractor sued the A/E for the rework costs that resulted because of negligent supervision. The A/E's lawyers argued the case should be dismissed because their client did not have a contract with the construction contractor. The court held that the rule requiring privity in this type of case was no longer valid. The court concluded that an A/E negligent in performance may be held liable to the construction contractor or any third party. The courts reasoning was that:

> Considerations of reason and policy impel the conclusion that the position and authority of a supervising architect are such that he ought to labor under a duty to the prime contractor to supervise the project with due care under the circumstances, even though his sole contractual relationship is with the owner, here the United States. Altogether too much control over the contractor necessarily rests in the hands of the supervising architect for him not to be placed under a duty imposed by law to perform without negligence his functions as they affect the contractor. The power of the architect to stop the work done is tantamount to a power of economic life or death over the contractor. It is only just that such authority, exercised in such a relationship, carry commensurate legal responsibility.[Ref. 1, p. 6]

This ruling implied that the A/E could be exposed to potential liability from any professional contacts, whether a contractual relationship existed or not.

The key to the above case, as well as the many that have followed, is that privity of contract no longer can be used as a legal defense by A/Es against construction contractors. Where the A/E actions or inactions lead a construction contractor down a path where the contractor suffers economic damage, and it can be shown that the A/E was negligent, the A/E is liable to the construction contractor for the economic damages. Negligence by the A/E leads to A/E liability. "One is not 'negligent' unless he fails to exercise that degree of reasonable care that would be exercised by a person of ordinary prudence under all the existing circumstances in view of probable danger of injury" [Ref. 2] A/Es can only be found negligent if they fail to exercise ordinary skill in their involvement in a project.

C. ORDINARY SKILL

A/Es are expected to use ordinary skill and care in all aspects of their involvement in a construction project. There are numerous types of deficiencies that may occur if normal or ordinary skill is not exercised. They include

> defects and deficiencies in the preparation of the plans and specifications; the failure to properly supervise the project; the unreasonable delay by the architect in preparation of revised plans and specifications; unreasonable delay in the issuance of change orders; failure to properly check or approve submittals, such as shop drawings; and the improper directives that an architect may give to anyone working on the project.[Ref. 1, p. 8]

Along with these items, risk factors exist concerning the A/E liabilities for:

a) Failure to observe traditional responsibilities to employ reasonable judgement, diligence and care.

b) Failure to deploy adequate numbers of personnel to perform work on a timely basis.

c) Failure to take "all measures" in counseling a client about his options, or to bring about full analysis of all risks among project participants.

d) Failure to, provide all legal, code, regulatory, safety, equal employment opportunity or QA/QC requirements in design.

e) Failure to warn or properly evaluate an owner's potential risk in accepting an innovation in concept or new material.

f) Failure to provide adequate contract conditions for guidance of suppliers and contractors to define interface responsibilities noting proper accountability for same.[Ref. 3, p. 7, Vol. 1]

In any of the above events the A/E's responsibilities are " to exercise the 'ordinary, reasonable technical skill, ability and competence' that would be expected of a qualified professional in a similar situation" [Ref. 1, p. 7].

The failure to use due care while involved in a construction project does not automatically cause A/E liability. If a design error existed in a project, and the A/E corrected the error in such a way as to prevent damage to the construction contractor, there would be no liability. Even if the arrangement between the owner and the A/E specifies the highest standards of the profession, "the architect will only be held to the normal standard of the profession in actions brought by third parties for negligence" [Ref. 1, p. 46].

> The architect's liability is tied directly to the obligations assumed under his contract with the owner. To the extent that the architect contracts to assume broader responsibility in connection with the administration of the construction project, he must be prepared to discharge that responsibility with the same care, skill, knowledge and dispatch that a court will find an ordinary member of his profession would exercise in the performance of such obligations. His failure to do so will subject him to either (1) derivative liability to contractors in suits by owners for indemnification for delay damages being sought by the contractor by virtue of the architect's breach of his contract with the owner; or (2) direct liability to the contractor for delay damages resulting from his failure to perform with do care the obligations undertaken. [Ref. 1, p. 49]

Negligence for A/Es is tied directly to their obligations and to their skill and care in performing those obligations. A good definition of negligence is as follows:

> A person is negligent when he fails to exercise ordinary care. Ordinary care is the degree of care which the great mass of mankind ordinarily exercises under the same or similar circumstances. A person fails to exercise ordinary care when, without intending to do any wrong, he does an act or omits a precaution under circumstances in which a person of ordinary intelligence and prudence ought reasonably to foresee that such act or omission will subject him or his property, or the person or property of another to an unreasonable risk or damage. [Ref. 4, p. 31]

The A/Es are at risk in any contract with an owner for services pertaining to a construction project. If the construction contractor is economically damaged because the A/E failed to use ordinary skills, the A/E can be held liable to the construction contractor for those damages. What happens in this situation when the owner is the United States Government?

D. THE GOVERNMENT AS THE OWNER

For most Government construction projects an A/E provides the design. This usually includes the plans and specifications, as well as follow-on services of construction site visits, design error or omission corrections, and submittal review. Submittals are product descriptions of the equipment the construction contractor intends to install. These submittals are sent to the A/E for review to insure that the equipment complies with the contract specifications.

The Congress of the United States authorizes and appropriates the money for Military Construction projects. Organizations such as Western Division, Naval Facilities Engineering Command (WESTDIV) will then contract with an A/E firm for design services. The completed plans and specifications are then advertized and awarded, in accordance with the Federal Acquisition Regulations, to the low responsive responsible bidder for construction. The owner's representative in the field is the Resident Officer in Charge of Construction (ROICC), who has day to day inspection responsibilities. The ROICC submits routine correspondence, submittals, and requests for information from the construction contractor to the A/E as well as to WESTDIV. It is the ROICC's responsibility to take steps necessary to insure a timely response for this information.

The request for information and correspondence often points out design deficiencies (errors or omissions) in the plans and specifications. The correction of these deficiences usually causes economic damage to the construction contractor. The Government then must pay the construction contractor for the amount of the damages incurred. In the past the Government rarely pursued remuneration for these damages caused by the A/E. The Government just did not hold the A/E liable for their actions.

> On July 14, 1977, the Comptroller General of the United States, in a report to Congress, advised the Congress that the agencies of the Federal Government have been required to pay to construction contractors large amounts of money because of negligent errors and/or omissions in the plans and specifications prepared by A/Es engaged by the Government. The report states that the agencies have not made a serious effort to document the design deficiences (to describe the deficiency and the extent and the *character of the A/E's involvement and responsibility)* althought required to do so by regulations and procedures established for such agencies. Secondly, that the agencies were not attempting to recover from the A/E the additional cost incurred by the Government as a result of these design deficiencies. Finally, the agencies have not been evaluating the A/E's performance properly and have not coordinated the information regarding the A/E's performance and have not disseminated the information to the other agencies employing A/E's. [Ref. 5, p. 1]

The above GAO report has lead to several changes in the way the Naval Facilities Engineering Command (NAVFAC) does business. The NAVFAC Contracting Manual contains the following discussion:

> a. For the purpose of these criteria, a design deficiency is any deficiency in the designs, drawings and specifications that may result in the Government incurring damages. A-E liability for a design deficiency may

result from either an A-E's negligent failure to meet the standard of care reasonably associated with the A-E profession or its breach of a contractual duty of skill and care in performing design services The determination of A-E liability requires answering afffirmatively the following questions:

(1) Is the construction modification attributable to a design deficiency?

(2) Does the design deficiency stem from an error or omission by the A-E?

(3) Does the design deficiency by the A-E result from the A-E's negligent failure to meet the standard of care reasonably associated with the A-E profession or from a breach of contractual duty?

(4) Has the Government suffered damage as a result of the design deficiency?

b. Irrespective of whether A-E liability is pursued under a tort or a contractual theory, the professional standard of care to be applied is the same standard used in cases involving alleged malpractice of doctors, lawyers and other professionals who sell their services for compensation. This standard essentially requires an A-E to exercise such reasonable care, skill and diligence as one in that profession would ordinarily exercise under similar circumstances. Failure to exercise normal skill and competence is usually negligence. Howerver, consideration should be given to representations of special skills and abilities made by the A-E and relied upon by the Navy in the selection progress. If negligence is believed to be involved, documentation should clearly state so. An A-E's performance must be negligent in order for the Government to collect for damages.[Ref. 6, p. J-2]

Once again, the A/E failure to exercise ordinary skill and competence leads to negligence. The economic damage to the Government from a design deficiency must be evaluated. The construction contractor is entitled to all valid costs incurred as a result of a change order to the plans and

specifications. The Government is responsible for paying those costs "for additional work which would have increased the original bid had the additional work been reflected in the original contract documents" [Ref. 5, p. P2]. The cost for this additional work is considered value added. However, unproductive costs associated with the additional work (for which the construction contractor is also entitled to compensation) are considered in the A/E liability category. The unproductive A/E liability costs are generally limited to the following:

(a) Tear out and replacement costs;

(b) Restocking and rehandling of materials delivered but no longer required;

(c) Delay costs (extended overhead and impact costs);

(d) Government investigation and design costs;

(e) A/E field visits costs;

(f) Input costs on unitemized work. [Ref. 5, p. 2]

Normally the A/E will not pay any of these costs at the time of the change. This means that the Government must pay the construction contractor for not only the value added portion of the change but also all of the costs associated with A/E liability. The Government must then pursue remuneration for the A/E liability.

III. METHOD OF RESEARCH

A. INTRODUCTION

Western Division, Naval Facilities Engineering Command provided the data source for this study. WESTDIV's primary mission includes the design, construction and maintenance of public works, public utilities, special facilities, public housing and vehicle management. WESTDIV, located in San Bruno, California, provides support to United States Navy activities and some other Federal Agency activities in the western part of the United States and Alaska. An extensive information data base provides documentation of all WESTDIV awarded A/E contracts and construction contracts. From this data base the following information was obtained for each project: the A/E contract number; the A/E's name; the design costs, the Construction Contract Support Service costs; the amount of A/E liability, if any; the settlement amount; the construction contract number, the contractor's name; the award amount; the construction modification amount; and the type of facility. These data were used to study relationships leading to an A/E liability prediction model. Assuming a significant relationship existed, the incidence and amount of A/E liability

could be predicted. Management ccould use this information to predict the incidence of A/E liability. Management would then be more alert for opportunities to minimize design differences.

B. THE SAMPLE

The primary data source came from the "A-E liability processing status log" (the log) of 1 July 1986. The log was composed of about 110 projects, from 1976 to 1984, which contained at least one design coded change order. A project with a construction contract change order resulting from a design error or omission is considered a design coded change. The log included the A/E contract number and the Construction Contract number, the title and location of the project, the A/E Responsibility Board meeting action date, the date a letter was sent to the A/E requesting settlement, the amount of potential liability, the status of processing, and the settlement received. The A/E Responsibility Board (the board) is composed of members from the design, construction, and contracts departments, a legal counsel, and a recorder, and is chaired by the head of the acquisition department. The board "prepares final determination to pursue or not pursue A-E liability. . ." [Ref. 7, p. 5].

The A/E and construction contract numbers from the log were used to create two more files from the data base. The first file, the A/E costs,

contained the total A/E costs associated with each project. These costs included the initial award amount, any modifications to the contract during project design, and Construction Contract Support Services (CCSS). CCSS is for follow-on services such as construction site visits, submittal reviews, etc. The second file, the construction contractor costs, provided the total cost paid to the construction contractor for each project. The costs included the initial award amount plus any modifications to the contract.

The three sources of data were then compiled for a total usable data base of 91 projects. For a few projects the contract numbers on the Log were not listed correctly. This led to no data or erroneous data on the A/E cost or the construction contract cost files. There were also a few inadvertent omissions or errors in entering the contract number into the data base to obtain the cost files. Only those projects which had the data from all three sources were used.

C. LIABILITY

When an apparent design deficiency occurs during the construction of a project, the ROICC is required to submit a Determination and Findings (D&F) to WESTDIV. "A D&F is a written statement of relevant facts, determinations, findings, and recommendations pertinent to change orders involving potential A-E liability" [Ref. 8, p. 3]. This D&F is reviewed by

several people within WESTDIV. These include the Engineer in Charge of the project, the head of the Design Department, the head of the Construction Department, and the A/E Responsibility Board. All of the above people make recommendations to pursue or not pursue A/E liability. In fact, most of the D&Fs do not lead to A/E liability. Where the head of the Construction Department and head of Design Department agree not to pursue A/E liability, the D&F is not forwarded to the board.

This study included only those projects where a D&F was forwarded to the board. If the board recommended no liability, then compiled research data (Appendix A) show no liability for the particular project. When the board recommended pursuing liability, the estimated potential liability amount is shown in Appendix A. The board's determination on A/E liability was considered the most appropriate place to first consider a project as containing A/E liability. When the board recommends pursuing A/E liability, a letter so stating is forwarded to the A/E. During this study, efforts were taken to prove a relationship existed between the incident of A/E liability and job complexity.

D. JOB COMPLEXITY

The job complexity was broken into three category codes, not complex (NC), complex (C), and very complex (VC). These codes were assigned on the

basis of the following list of construction project characteristics:

Number	Weight	Characteristic
1.	1	Additions to existing structures, mechanical systems, electrical systems, etc.
2	1	Multi-story construction
3.	2	Very specialized construction (e.g., missile magazines)
4.	1	Very hazardous construction
5.	1	Special security requirements
6	1	Exceptional unforseen conditions

The project was considered not complex if from zero to one of the above characteristics was present, complex if two to three were present, and very complex if four or more were present. Equal weight was given to all of the characteristics, with the exception of the very specialized construction, which was given a double weight. The nature of specialized construction alone was considered enough to increase the complexity of a construction project at least into the complex range. The complexity codes were assigned to the 91 projects studied in an objective manner based on the presence or absence of the six construction project characteristics. The complexity codes were then used to establish the analysis groups for the data collected. [Ref. 9, p. B-IX]

E. ANALYSIS

The three complexity codes (not complex, complex and very complex) determined in which group each contract was to be analyzed. For example, in the not complex group two different regression models were set up. First, the amount of liability was regressed against the A/E costs and then the amount of liability was regressed against the construction costs. These regressions were done for all three complexity codes to determine existing correlation patterns. The regression analysis was then performed on the combined data from the three complexity groups. The actual analysis procedures and results are described in the next chapter.

IV. ANALYSIS

A. INTRODUCTION

The primary goal of analyzing the 91 projects in Appendix A was to establish a relationship to predict the amount of A/E liability on future contracts. Regression was used to show the relationship. "Regression is a technique of quantifying relationships between variables" [Ref. 10, p. 1 Chap.2]. The regression analysis was done with a Minitab computer software program on the Naval Postgraduate School's IBM 3033 computer. First the data from Appendix A were compiled into three groups - not complex, complex, and very complex projects. Then, in each group, A/E liability (column #8 in Appendix A) was regressed against the A/E costs (column #4 in Appendix A), against construction costs (column #6 in Appendix A), and finally against both A/E costs and construction costs in a multiple regression analysis. Two explanatory variables, A/E costs and construction costs, were used because they could be reliably measured. The explanatory variables are used in an equation to predict the dependent variable, A/E liability in this case.

For each project, the award amount for the design contract and all contract modification costs are included in the A/E costs column (column #3 in Appendix A). These costs are known with certainty at the time of award of the construction contract. The project design is complete and all of the costs for the design have been paid. Although the construction contract support services (CCSS) costs are negotiated with the A/E at about the same time as the construction contract award, they may be amended during the course of the construction. The historical data for the 91 projects studied included the CCSS costs. At the time of award of a new construction contract, the CCSS costs would not be known with certainty. Therefore, the CCSS costs could skew the results of a prediction model. The CCSS costs of the 91 projects were removed from the A/E design costs and not included in this study (the data in columns #3 and #4 in Appendix A did not include CCSS costs).

The construction costs (columns #5 and #6 in Appendix A) contain only the amount originally awarded for the contract. This figure is known with certainty at the time of award. Although the construction modification costs were known for the 91 projects studied, only an estimate could be used for a new project. The uncertainty of the modification costs could skew the results of a prediction model. Therefore, the modification costs

of the 91 projects were deducted from the construction costs and not included in this study.

Prior to running any analysis, the data were adjusted for the effects of inflation. Inflation can cause contamination of the data and skew or invalidate the regression model. "The data should be expressed in constant dollars to avoid contamination by changes in the price levels over time" [Ref. 10, p. 31, Chap. 2]. The inflation adjustment is made by using the New Construction Index which is obtained by studying the variations in costs from year to year of similar construction projects. The differences in costs are due to inflation or deflation. A base year is arbitrarily picked and set equal to 100. Dividing 100 by the index number for another year provides a correction factor for that year. When multiplied by the correction factor, the construction costs for that year can then be compared to the base year without effects of inflation. The New Construction Index used 1977 as the base year [Ref. 11 and 12]. The index and the correction factor were displayed in Appendix B for the years 1975 through 1984. The data in Appendix A were adjusted to 1977 constant dollars. Columns #4, 6, 8, and 10 of Appendix A contain the inflation adjusted costs - #4, adjusted A/E costs; #6, adjusted construction costs; #8, adjusted A/E liability; and #10, adjusted amount of liability settlement. The years of the contracts

for the design and construction of the project are listed in column *1 in Appendix A. When the year for the design and the construction is the same, only one year is listed.

As stated above, the explanatory variables are known with certainly, not only for the the 91 projects studied but also for any future project at the time of construction contract award. Now all that is needed is a mathematical equation to predict the amount of A/E liability on future contracts by reference to the values of the known variables.

B. REGRESSION ANALYSIS OF NOT COMPLEX PROJECTS

There were 34 projects in the not complex (NC) category. Appendix C contains the data and all of the regression analysis results. The A/E and construction cost figures in Appendix A were recorded to the nearest thousand dollar level, so after the data from the 34 NC projects were entered into the computer the A/E costs and the construction costs were both multiplied by 1000. There are five columns of data in Appendix C. They are C1, a numerical listing of the projects; C2, the A/E costs in thousands; C3, construction costs in thousands; C4, A/E liability; C5, the A/E costs; and C6, the construction costs. The first regression of A/E liability (C4) against the A/E costs (C5) was performed. The equation for each regression is provided in the Appendix. In this case the equation is: A/E liability

(C4) = 21366 + 0.0257 x A/E costs(C5). This equation has a coefficient of determination (R^2) of only 4.9%. This means that 4.9% of the sample variation in A/E liability, the dependent variable, can be explained by the change in A/E costs, the independent variable. [Ref. 10, p. 13, Chap. 2] An R^2 of 4.9% means the regression equation is a very poor predictor.

From here on only the R^2 value will be discussed; the equations will not be included in the body of this paper unless the regression equation is significant, as determined by R^2 and other factors. Appendix C contains all of the equations. A histogram of A/E liability costs (C4) was plotted to determine if a normal distribution of data existed. (A histogram is a graph of a frequency distribution in the form of a series of rectangles, each proportional in width to the range of values within a class and proportional in height to the number of items falling in the class.) The midpoint of the range and the count of the number of items falling in each range, along with a graphical presentation of the distribution, are included in Appendix C. Regression models are based on "...the assumption that the values of the dependent variable are normally distributed" [Ref. 10, p. 3, Chap. 4]. The data for the dependent variable, A/E liability costs (C4), were not normally distributed. The data can be transformed in several ways, however, to obtain a more normal distribution. The logarithmic, square root and

reciprocal functions were the only ones used during this study. For instance, the square root of each dependent data point of A/E liability (C4) was taken and then plotted on a histogram. The square root of A/E liability (C10) was the new variable. The histogram of the square root of A/E liability (C10) was more normally distributed than the histogram of A/E liability (C4). The square root of A/E liability (C10) was then regressed against A/E costs (C5) for an R^2 of 6.6%. R^2 values of less then 30% for the regression model indicate a very poor predictor. Therefore, other regressions were tried.

The square root of A/E liability (C10) was then regressed against the construction costs (C6) to produce an R^2 of 0.5%. The A/E liability (C4) was then regressed against the construction costs (C6) to see if a better model could be obtained without the transformation. R^2 was 1.7%. The dependent variable may also be transformed. First the histograms of A/E costs (C5) and construction costs (C6) were plotted to determine that the data were not normally distributed for either. Three transformations of A/E costs (C5) were then tried (the reciprocal, the logarithm, and the square root) and the associated histograms were plotted. The square root of A/E costs (C13) produced the most normal distribution. Three transformations of the construction costs (C6) were tried (the reciprocal, the logarithm,

and the square root) and the associated histograms were plotted. The square root of construction costs (C17) produced the most normal distribution. The square root of A/E liability (C10) was regressed against the square root of A/E costs (C13) for an R^2 of 5.0%. The square root of A/E liability (C10) was regressed against the square root of construction costs (C17) for an R^2 of 5.9%.

Next, a multiple regression was performed. The square root of A/E liability (C10) was regressed against both the square root of A/E costs (C13) and the square root of construction costs (C17), producing an R^2 of 6.8%. Not only was the R^2 value very low, but the t-ratio values of 0.54 for the square root of A/E costs (C13) and 0.77 for the square root of construction costs (C17) were also too low. The t-ratio provides a test for the statistical significance of the regression line. "A high t-value indicates that the independent variable is important in explaining the value of Y. Generally, t-values of greater than two are desired..."[Ref. 10, p. 17, Chap. 1]

At this point in the analysis no significant relationship had been found, so a plot of the A/E liability (C4) against the A/E costs (C5) and a plot of A/E liability (C4) against construction costs (C6) were reviewed for outliers. Data points which are far beyond the main body of data are considered outliers, outliers can skew the regression analysis and should be eliminated

During the regression analysis the computer program notes unusual observations. These unusual observations in this study included data points, by number, with a large influence on the regression equation. Outlier data points #9, 14 and 25 are circled in Appendix C on the plot of A/E liability (C4) against A/E costs (C5). Outlier data point #8 is circled in Appendix C on the plot of A/E liability (C4) against construction costs (C6). These four data points were all outside the main body of the data because of extremely high construction costs or A/E design costs relative to the other NC data points. These four data points were then deleted from the NC data. The NC data were then printed showing only 30 rows of data elements. Note that column C1 contains the original numerical listing for the project. The same process was used to evaluate the revised NC data. First the square root of A/E liability (C20) transform was calculated and its histogram was plotted. The regression of A/E liability (C4) against A/E costs (C5) produced an R^2 of 10.9% and the regression of the square root of A/E liability (C20) against A/E costs (C5) resulted in an R^2 of 12.1%. Next, the A/E liability (C4) was regressed against the construction costs (C6) and generated an R^2 of 26.2%. The regression of the square root of A/E liability (C20) against the construction costs (C6) produced an R^2 of 21.6%. These values of R^2 are much better than what was obtained before deleting the outliers. However,

the values are still very low. Some additional steps were taken to try for improved R^2 values.

The square root of A/E costs (C21) was calculated and the histograms for A/E costs (C5) and the square root of A/E costs (C21) were plotted, and they show that the square root of A/E costs (C21) is more normally distributed. Regressing the square root of A/E liability (C20) against the square root of A/E costs (C21) resulted in an R^2 of only 3.8%. The square root of construction costs (C22) was calculated and the histograms for construction costs (C6) and the square root of construction costs (C22) were plotted, indicating that the square root of construction costs (C22) is more normally distributed. The square root of A/E liability (C20) was then regressed against the square root of construction costs (C22), producing an R^2 of 20.9%. Once again the plots of A/E liability (C4) against construction costs (C6) and A/E liability (C4) against A/E costs (C5) were reviewed for outliers. Outlier data points #5, 16 and 20 were circled on the plots and then deleted from the NC data.

After the revised data were printed, the square root of A/E liability (C30) was calculated and its histogram plotted. The regression of A/E liability (C4) against A/E costs (C5) resulted in an R^2 of 29.0%, while the regression of the square root of A/E liability (C30) against A/E costs (C5)

produced an R^2 of 26.9%. The square root of A/E costs (C31) and its histogram were calculated and plotted. The regression of the square root of A/E liability (C30) against the square root of A/E costs (C31) generated an R^2 of 19.0%. An R^2 value of 28.5% resulted from the regression of A/E liability (C4) against the construction costs (C6). The histogram of the construction costs (C6) was plotted and compared to the following transformations: the square root of construction costs (C32) and the logarithm of construction costs (C33). None of these histograms was very normally distributed; however, the logarithm of construction costs (C33) was the closest. The A/E liability (C4) was regressed against the logarithm of construction costs (C33), resulting in an R^2 of 16.1%. The regression of the square root of A/E liability (C30) against the logarithm of construction costs (C33) produced an R^2 of 16.3%. The multiple regression of A/E liability (C4) against both A/E costs (C5) and construction costs (C6) produced an R^2 of 32.9%. However, the t-ratios for both independent variables were too low and the equation should not be used. Another multiple regression was tried - A/E liability (C4) against both the square root of A/E costs (C31) and the square root of construction costs (C32). This produced an R^2 of 24.4%. The regression of A/E liability (C4) against the square root of construction costs (C32) resulted in an R^2 of 22.1%,

while the regression of the square root of A/E costs (C30) against the square root of construction costs (C32) produced an R^2 of 17.6%.

From this point in the analysis the plots of A/E liability (C4) against A/E costs (C5) and A/E liability against (C4) construction costs (C6) were again reviewed. Two more outliers were deleted from the data and the regression analysis was started over again. The resulting regressions, using both nontransformed and transformed data, generated R^2 values of less than 15%, less than those produced before deleting the last two outliers. One more data point was deleted in an effort to improve the regression equations. Once again, the resulting R^2 values were very low. No more data points were then deleted. The regression equations were not improving with the deletion of more data and the data base was getting too small to be representative of the initial data.

After deleting seven data elements the best result was an R^2 of 29.0%. The regression equation is: A/E liability (C4) = -4741 + 0.0898 x A/E costs (C5). The t-ratio for the independent variable was 3.19. This means that 29.0% of the variation in A/E liability can be explained by the change in A/E costs. Even though this was the best relationship for A/E liability, the regression equation does not provide enough of a relationship to be useful in predicting A/E liability.

C. REGRESSION ANALYSIS OF COMPLEX PROJECTS

There were 46 projects in the complex category from the data in Appendix A. Appendix D contains the data and all of the regression analysis. The A/E costs and the construction costs were each multiplied by one thousand so that all of the data were in the same units. The five columns in Appendix D contain the same types of data as the five columns in Appendix C. The first two regressions run were A/E liability (C4) against A/E costs (C5), producing an R^2 of 0.0%, and A/E liability (C4) against construction costs (C6), resulting in an R^2 of 1.0%. The histogram of A/E liability (C4) was plotted and then compared to the histogram of the transformation of the square root of A/E liability (C10). The square root of A/E liability (C10) was regressed against A/E costs (C5), resulting in an R^2 of 0.4%. Then the square root of A/E liability (C10) was regressed against construction costs (C6), producing an R^2 of 0.8%. The histograms of A/E costs (C5) and construction costs (C6) were then plotted and compared to several transforms. The reciprocal, logarithm, and square root transforms were tried on the A/E costs (C5); the resulting histograms indicated that the logarithm of A/E costs (12) was the most normal. The logarithm and the square root transforms were then tried on the construction costs (C6); the respective histograms indicated that the square root of construction costs

(C15) was the most normal. A/E liability (C4) was then regressed against the logarithm of A/E costs (C12), producing an R^2 of 2.9%. The square root of A/E liability (C10) was regressed against the logarithm of A/E costs (C12), resulting in an R^2 of 5.8%. Two more regressions were then performed. The first was A/E liability (C4) against the square root of construction costs (C15), resulting in an R^2 of 1.9%. The second was the square root of A/E liability (C10) against the square root of construction costs (C15), producing an R^2 of 2.6%. A multiple regression of the square root of A/E liability (C10) against the logarithm of A/E costs (C12) and the square root of construction costs (C15) generated an R^2 of 5.8%. None of the R^2 values was significant, so the plots of A/E liability (C4) against A/E costs (C5) and A/E liability (C4) against construction costs (C6) were reviewed for outliers. Data elements # 4, 38 and 40 are outliers and have been circled on the plots in Appendix D.

Those three data elements were then deleted from the set of complex data, and the revised data were printed in Appendix D. The A/E liability (C4) was transformed into the square root of A/E liability (C20) and both histograms were plotted. The square root of A/E liability (C20) was more normally distributed. Four regressions were then run to check for a good model. The A/E liability (C4) was regressed against A/E costs (C5), the

square root of A/E liability (C20) was regressed against A/E costs (C5), A/E liability (C4) was regressed against construction costs (C6), and the square root of A/E liability (C20) was regressed against construction costs (C6). These four regressions generated respective R^2 values of 5.4%, 6.2%, 0.9%, and 0.7%. The A/E costs (C5) were then transformed into the square root of A/E costs (C21) and the logarithm of A/E costs (C22). The histograms of all three were plotted, and indicated that the square root of A/E costs (C21) was more normal. The construction costs (C6) were then transformed into the square root of construction costs (C23), and the histogram indicated this was a normal distribution. The following five regressions were then run: A/E liability (C4) against the square root of A/E costs (C21), the square root of A/E liability (C20) against the square root of A/E costs (C21), A/E liability (C4) against the square root of construction costs (C23), the square root of A/E liability (C20) against the square root of construction costs (C23), and finally, the multiple regression of the square root of A/E liability (C20) against both the square root of A/E costs (C21) and the square root of construction costs (C23). The respective R^2 values of these five regressions were 7.2%, 8.5%, 3.0%, 3.3%, and 8.5%. None of the R^2 values was significant, so the plots of A/E liability (C4) against A/E costs (C5) and A/E liability (C4) against construction costs

(C6) were reviewed for outliers. Data elements # 4, 11 and 33 are outliers and have been circled on the plots in Appendix D.

The three outliers were then deleted from the set of complex data, and the revised data were printed in Appendix D. The A/E liability (C4) was transformed into the square root of A/E liability (C30), and both histograms were plotted. The square root of A/E liability (C30) was more normally distributed. Four regressions were then run to check for a good model. The A/E liability (C4) was regressed against A/E costs (C5), the square root of A/E liability (C30) was regressed against A/E costs (C5), A/E liability (C4) was regressed against construction costs (C6), and the square root of A/E liability (C30) was regressed against construction costs (C6). These regressions produced R^2 values of 1.6%, 3.6%, 8.4%, and 7.3%, respectively.

The A/E costs (C5) were then transformed into the square root of A/E costs (C31) and both histograms were plotted, indicating that the square root of A/E costs (C31) was a little more normally distributed. The construction costs (C6) were transformed into the square root of construction costs (C32) and the logarithm of construction costs (C33). The three associated histograms were plotted, indicating that the construction costs (C6) were the most normal. Regressions against the square root of construction costs (C32) and the logarithm of construction

costs (C33) were not run because the construction costs (C6) was more normally distributed. The following three regressions were run: A/E liability (C4) against the square root of A/E costs (C31), the square root of A/E liability (C30) against the square root of A/E costs (C31), and the multiple regression of the square root of A/E liability (C30) against both the square root of A/E costs (C31) and the construction costs (C6). These tests resulted in respective R^2 values of 4.2%, 6.9%, and 8.8%. The R^2 value of 8.8% was disregarded because of the very low t-ratio values of 0.79 for the square root of A/E costs (C31) and 0.90 for the construction costs (C6). None of the R^2 values was significant, so the plots of A/E liability (C4) against A/E costs (C5) and A/E liability (C4) against construction costs (C6) were reviewed for outliers. However, no more data points were deleted. The regression equations were not improving with the deletion of more data, and the data base was becoming too small to be representative of the initial data.

The regression of the square root of A/E liability (C20) against the square root of A/E costs (C21), after deleting three data elements, produced the best R^2 value of 8.5%. The regression equation is: the square root of A/E liability (C20) = 45.5 + 0.119 x the square root of A/E costs (C21). The t-ratio for the independent variable was 1.95. This means that

8.5% of the sample variation in the square root of A/E liability can be explained by the change in the square root of A/E costs. Even though this was the best relationship for A/E liability, the regression equation does not provide enough of a relationship to be useful in predicting A/E liability.

D. REGRESSION ANALYSIS OF VERY COMPLEX PROJECTS

There were 11 projects in the very complex category from the data in Appendix A. Appendix E contains the data and all of the regression analyses. The A/E costs and the construction costs were each multiplied by one thousand, so all of the data were in the same units. The five columns in Appendix E contain the same types of data as the five columns in Appendices C and D. The first two regressions run were A/E liability (C4) against A/E costs (C5), with an R^2 of 3.5%, and A/E liability (C4) against construction costs (C6), resulting in an R^2 of 0.0%. The histogram of A/E liability (C4) was plotted and then compared to the histogram of the transformation of the square root of A/E liability (C10). The square root of A/E liability (C10) was regressed against A/E costs (C5), resulting in an R^2 of 5.4%. Then the square root of A/E liability (C10) was regressed against construction costs (C6), producing an R^2 of 0.5%. The histograms of A/E costs (C5) and construction costs (C6) were then plotted and compared to several transforms. The square root, logarithm, and reciprocal transforms

were tried on the A/E costs (C5); the resulting histograms indicated the square root of A/E costs (11) was the most normal. The square root and the logarithm transforms were tried on the construction costs (C6); the respective histograms indicated that the logarithm of construction costs (C15) was the most normal. A/E liability (C4) was then regressed against the square root of A/E costs (C11), producing an R^2 of 2.6%. The square root of A/E liability (C10) was regressed against the square root of A/E costs (C11), resulting in an R^2 of 4.2%. Two more regressions were then performed. The first was A/E liability (C4) against the logarithm of construction costs (C15), resulting in an R^2 of 1.5%. The second was the square root of A/E liability (C10) against the logarithm of construction costs (C15), producing an R^2 of 0.2%. A multiple regression of the square root of A/E liability (C10) against the A/E costs (C4) and the construction costs (C6) generated an R^2 of 5.8%. None of the R^2 values was significant, so the plots of A/E liability (C4) against A/E costs (C5) and A/E liability (C4) against construction costs (C6) were reviewed for outliers. Data element *3 is an outlier and has been circled on the plots in Appendix E.

Data element *3 was then deleted from the set of very complex data, and the revised data were printed in Appendix E. The A/E liability (C4) was transformed into the square root of A/E liability (C20) and both histograms

were plotted, indicating that the square root of A/E liability (C20) was more normally distributed. Four regressions were then run to check for a good model. The A/E liability (C4) was regressed against A/E costs (C5), the square root of A/E liability (C20) was regressed against A/E costs (C5), A/E liability (C4) was regressed against construction costs (C6), and the square root of A/E liability (C20) was regressed against construction costs (C6). These regressions resulted in R^2 values of 9.7%, 6.6%, 9.3%, and 11.6%, respectively. The A/E costs (C5) were then transformed into the square root of A/E costs (C21), the logarithm of A/E costs (C22) and the reciprocal of A/E costs (C23). The histograms of all four were plotted, indicating that the square root of A/E costs (C21) was most normal. The construction costs (C6) were then transformed into the square root of construction costs (C24) and the logarithm of the construction costs (C25). The histograms indicated the logarithm of the construction costs (C25) was a normal distribution. The following five regressions were then run: A/E liability (C4) against the square root of A/E costs (C21), the square root of A/E liability (C20) against the square root of A/E costs (C21), A/E liability (C4) against the logarithm of construction costs (C25), the square root of A/E liability (C20) against the logarithm of construction costs (C25), and finally the multiple regression of the square root of A/E liability

(C20) against both the A/E costs (C5) and the construction costs (C6). The resulting R^2 values were 8.1%, 5.4%, 2.6%, 5.6%, and 17.3%, respectively. None of the R^2 values was significant, so the plots of A/E liability (C4) against A/E costs (C5) and A/E liability (C4) against construction costs (C6) were reviewed for outliers. Data element #9 is an outlier and has been circled on the plots in Appendix E.

This data element was then deleted from the set of very complex data and the revised data were printed in Appendix E. The A/E liability (C4) was transformed into the square root of A/E liability (C30), and both histograms were plotted. The square root of A/E liability (C30) was more normally distributed. Four regressions were then run to check for a good model. The A/E liability (C4) was regressed against A/E costs (C5), the square root of A/E liability (C30) was regressed against A/E costs (C5), A/E liability (C4) was regressed against construction costs (C6), and the square root of A/E liability (C30) was regressed against construction costs (C6). The respective R^2 values were 14.7%, 6.8%, 8.4%, and 9.9%. The A/E costs (C5) were then transformed into the square root of A/E costs (C31), the logarithm of A/E costs (C32) and the reciprocal of A/E costs (C33). The four histograms were plotted, indicating the square root of A/E costs (C31) was a little more normally distributed. The construction costs (C6) were

transformed into the square root of construction costs (C34) and both histograms were plotted, indicating the square root of construction costs (C34) was a little more normally distributed. The following five regressions were then run: A/E liability (C4) against the square root of A/E costs (C31), the square root of A/E liability (C30) against the square root of A/E costs (C31), the A/E liability (C4) against the square root of construction costs (C34), the square root of A/E liability (C30) against the square root of construction costs (C34), and the multiple regression of A/E liability (C4) against both the square root of A/E costs (C31) and the square root of construction costs (C34). These regressions resulted in respective R^2 values of 17.3%, 7.7%, 6.0%, 8.5% and 21.6%. The R^2 value of 21.6% was disregarded because of the very low t-ratio values of -1.09 for the square root of A/E costs (C31) and -0.57 for the square root of construction costs (C34). None of the R^2 values was significant, so the plots of A/E liability (C4) against A/E costs (C5) and A/E liability (C4) against construction costs (C6) were reviewed for outliers. No more data points were deleted. The regression equations were not improving significantly with the deletion of more data, and the data base was becoming too small to be representative of the initial data.

The regression of A/E liability (C4) against the square root of A/E costs (C31), after deleting two data elements, produced the best R^2 value of 17.3%. The regression equation is: A/E liability (C4) = 72507 - 19.8 x the square root of A/E costs (C31). The t-ratio for the independent variable was -1.21. This means that 17.3% of the sample variation in A/E liability can be explained by the change in the square root of A/E costs but not significantly because of the low t-ratio. Even though this was the best relationship for A/E liability, the regression equation does not provide enough of a relationship to be useful in predicting A/E liability.

The three data sets (not complex, complex and very complex) reviewed did not produce a significant relationship for predicting the future amount of A/E liability. One last effort to form a predictive model was attempted. The three data sets were combined into one total data set, which was studied next.

E. REGRESSION ANALYSIS OF ALL PROJECTS

The three categories of projects combine for a total of 91 projects. Appendix F contains the data, compiled in order of complexity from not complex to very complex, and all of the regression analyses. The A/E costs and the construction costs were each multiplied by one thousand so that all of the data were in the same units. The five columns in Appendix F contain

the same types of data as the five columns in Appendices C, D and E. After the histogram of A/E liability (C4) was plotted and then compared to the histogram of the square root of A/E liability (C10), the first four regressions were run. These were: A/E liability (C4) against A/E costs (C5), the square root of A/E liability (C10) against A/E costs (C5), A/E liability (C4) against construction costs (C6), and the square root of A/E liability (C10) against construction costs (C6). These regressions resulted in the respective R^2 values of 0.1%, 0.5%, 1.9%, and 1.6%. The histograms of A/E costs (C5) and construction costs (C6) were then plotted and compared to several transforms. The square root, logarithm, and reciprocal transforms were tried on the A/E costs (C5); the resulting histograms indicated the logarithm of A/E costs (12) was the most normal. The square root, logarithm, and reciprocal transforms were tried on the construction costs (C6); the respective histograms indicated that the square root of construction costs (C14) was the most normal. A/E liability (C4) was then regressed against the logarithm of A/E costs (C12), producing an R^2 of 2.7%. The square root of A/E liability (C10) was regressed against the logarithm of A/E costs (C12), resulting in an R^2 of 4.9%. Two more regressions were then performed. The first was A/E liability (C4) against the square root of construction costs (C14), resulting in an R^2 of 3.5%. The second was the

square root of A/E liability (C10) against the square root of construction costs (C14), producing an R^2 of 5.0%. A multiple regression of the square root of A/E liability (C10) against the logarithm of A/E costs (C12) and the square root of construction costs (C14) generated an R^2 of 6.1%. None of the R^2 values was significant, so the plots of A/E liability (C4) against A/E costs (C5) and A/E liability (C4) against construction costs (C6) were reviewed for outliers. Data elements #38, 74, 81, 83, and 86 are outliers and have been circled on the plots in Appendix F.

The five data elements were then deleted from the set of data and the revised data were printed in Appendix F. The A/E liability (C4) was transformed into the square root of A/E liability (C20) and both histograms were plotted, indicating the square root of A/E liability (C20) was more normally distributed. Four regressions were then run to check for a good model. The A/E liability (C4) was regressed against A/E costs (C5), the square root of A/E liability (C20) was regressed against A/E costs (C5), A/E liability (C4) was regressed against construction costs (C6), and the square root of A/E liability (C20) was regressed against construction costs (C6). The respective R^2 values were 4.8%, 6.1%, 0.6%, and 0.4%. The A/E costs (C5) were then transformed into the logarithm of A/E costs (C21) and the histograms were plotted, indicating that the logarithm of A/E costs

(C21) was more normal. The construction costs (C6) were then transformed into the square root of construction costs (C22) and both histograms were plotted, indicating the square root of the construction costs (C22) was a normal distribution. The following five regressions were then run: A/E liability (C4) against the logarithm of A/E costs (C21), the square root of A/E liability (C20) against the logarithm of A/E costs (C21), A/E liability (C4) against the square root of construction costs (C22), the square root of A/E liability (C20) against the square root of construction costs (C22), and finally, the multiple regression of the square root of A/E liability (C20) against both the A/E costs (C5) and the square root of construction costs (C22). The resulting R^2 values were 3.6%, 4.4%, 3.0%, 3.3%, and 6.6%, respectively. None of the R^2 values was significant, so the plots of A/E liability (C4) against A/E costs (C5) and A/E liability (C4) against construction costs (C6) were reviewed for further outliers. Data elements #8, 9, 45, 71, 81, and 86 are outliers and have been circled on the plots in Appendix F.

Those six data elements were then deleted from the set of data and the revised data were printed in Appendix F. The A/E liability (C4) was transformed into the square root of A/E liability (C30) and both histograms were plotted, indicating the square root of A/E liability (C30) was more

normally distributed. Four regressions were then run to check for a good model. The A/E liability (C4) was regressed against A/E costs (C5), the square root of A/E liability (C30) was regressed against A/E costs (C5), A/E liability (C4) was regressed against construction costs (C6), and the square root of A/E liability (C30) was regressed against construction costs (C6). Respective R^2 values were 21.6%, 17.5%, 11.7%, and 10.2%. The A/E costs (C5) were then transformed into the logarithm of A/E costs (C31) and both histograms were plotted, indicating the logarithm of A/E costs (C31) was a little more normally distributed. The construction costs (C6) were transformed into the square root of construction costs (C32) and histograms were plotted, indicating that the square root of construction costs (C32) was normally distributed. The following five regressions were then run: A/E liability (C4) against the logarithm of A/E costs (C31), the square root of A/E liability (C30) against the logarithm of A/E costs (C31), the A/E liability (C4) against the square root of construction costs (C32), the square root of A/E liability (C30) against the square root of construction costs (C32), and the multiple regression of A/E liability (C4) against both the A/E costs (C5) and the square root of construction costs (C32). These regressions resulted in respective R^2 values of 8.4%, 7.6%, 14.0%, 13.1% and 23.0%. The R^2 value of 23.0% was disregarded because of

the very low t-ratio value of 1.19 for the square root of construction costs (C32). None of the R^2 values was significant, so the plots of A/E liability (C4) against A/E costs (C5) and A/E liability (C4) against construction costs (C6) were reviewed again for outliers. No more data points were deleted. The regression equations were not improving with the deletion of more data, and the data base was becoming too small to be representative of the initial data.

The regression of A/E liability (C4) against A/E costs (C5) after deleting eleven data elements produced the best R^2 value of 21.6%. The regression equation is: A/E liability (C4) = 9302 + 0.0460 x A/E costs (C5). The t-ratio for the independent variable was 4.64. This means that 21.6% of the sample variation in A/E liability can be explained by the change in A/E costs. Even though this was the best relationship for A/E liability, the regression equation does not provide enough of a relationship to be useful in predicting A/E liability.

F. CONCLUSIONS

A good mathematical equation to predict the amount of A/E liability on future projects was not found by regression analysis. One other relationship was then tried. A chart of the complexity of the projects was assembled and is shown in Appendix G. Six ranges of A/E liability (A/E)

were established, as follows: 0 (no liability), $0 < A/E \leq \$10,000$, $\$10,000 < A/E \leq \$50,000$, $\$50,000 < A/E \leq \$100,000$, $\$100,000 < A/E \leq \$500,000$, and $A/E > \$500,000$. The number of projects in each range from each complexity category was then listed. The percent of this number with respect to the total in the complexity category was calculated. Then the percent of this number in each range for all categories was calculated. Along the bottom of the chart the number of projects in each range was totaled. The percent of this number within the total 91 projects was calculated. The percent of projects with liability within each complexity category was calculated and shown on the bottom of the chart. Finally, for each category, the percent of the total was multiplied by the percent with liability. From these figures it can be seen that there is about an equal likelihood of an occurrence of A/E liability in the not complex and complex categories and a slightly higher chance of occurrence in the very complex projects. Since the number of very complex projects was limited there was little significance to the higher chance of A/E liability. Also, from the chart it can be seen that nearly three quarters (73.7%) of the projects had an A/E liability amount of less than \$50,000.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

This study found no significant relationships between A/E costs and /or construction costs and the amount of A/E liability. Although the data indicate that the very complex projects are more likely to have A/E liability than the complex or not complex projects, the relationship is not significant. No usable mathematical equation for predicting the amount of A/E liability was obtained through regression analysis. No usable information for predicting the incidence of A/E liability was found by this study.

B. RECOMMENDATIONS

The data studied did not lead to a mathematical prediction model. Therefore, recommendations are based on the literature researched. The construction manager should require the A/E that designed the project to be actively involved with the construction of the project. The A/E should be informed of any required changes to the design during the course of construction. In the case of a large change order or one in which A/E liability may be present, the A/E should be required to make a site visit.

During and subsequent to the site visit the A/E should provide one or more possible solutions to the construction problem.

The Government will be better off with greater A/E involvement. If there is any question concerning the responsibility for a construction problem, the Government should offer to pay the A/E site visit costs and any design/redesign costs associated with the construction problem. The A/E's design/redesign will probably be the best for the situation, because the A/E is most familiar with the criteria for the original design of the project. In the case where the construction problem is a result of an error or omission in the original design, the site visit and design/redesign costs may then be recovered from the A/E. Although the design/redesign costs may be difficult to recover, they are very small in comparison to the change order construction costs; and the potential to save on construction costs is great.

If the Government pursues A/E liability, the A/E community will attempt to provide a better design to minimize liability. With greater involvement of the A/E, better and more timely solutions to construction problems should result in lower change order costs. This means the Government will be getting improved designs from the A/E community. When construction problems arise, the problem will be resolved in a less costly manner - a "win-win" situation for all parties, especially the Government.

Future studies of A/E liability could be very beneficial to the Government. The A/E liability programs at all of the Navy's Engineering Field Divisions and large Officer in Charge of Construction offices could be analyzed to determine the best features, which could then be implemented at all divisions and commands. A couple of the attributes of these features could be as follows: a low A/E liability for the agency, measured by actual dollar or percent; and timely settlement of A/E liability, measured in days from the board decision to pursue until the settlement of A/E liability. New projects originating from WESTDIV are supposed to have weekly site visits by the A/E. These projects could also be analyzed to determine if the change order costs and the A/E liability are less than in the group studied for this thesis.

APPENDIX A

COMPILED RESEARCH DATA

#1 Job Description Year Designed Year Constructed	#2 Complexity	#3 A/E costs (000)	#4 adj A/E costs	#5 Const costs (000)	#6 adj Const costs	#7 A/E lia	#8 adj A/E lia	#9 Set amt	#10 adj set amt
1. Sub Training Fac. 76D 80C	NC	74	95	52	48	0	0	0	0
2. Bldg Envir Control 76D 78C	NC	92	116	664	584	4000	3520	0	0
3. Rpr Hydrostatic Relief 76D 78C	C	918	1166	1487	1308	4977	4380	IP	0
4. Barracks 76	NC	197	250	4890	6210	0	0	0	0
5. Steam/ Condensate Mod. 76	C	317	403	2732	3470	0	0	0	0
6. Life Safety Upgrade 76D 80C	C	811	1030	1876	1745	5804	5398	IP	-
7. Gas Processing Plant 76D 79C	VC	6702	8512	18567	15411	12234	10154	6117	5077
8. Elk Hills Tank Farm 76D 77C	C	7614	9670	10100	10100	21000	21000	0	0
9. Causeway/Bridge Alts 76D 77C	C	827	1050	13236	13236	0	0	0	0
10. Alter Hanger #3 77	C	14	14	2426	2426	25500	25500	0	0
11. A/C Maint Training Fac 77	C	391	391	5454	5454	12191	12191	12191	12191
12. Hanger Improvements 77	NC	166	166	3180	3180	0	0	0	0
13. Pipe & Copper Shop 77	VC	589	589	6928	6928	0	0	0	0
14. Rigging Shop 77	C	578	578	7690	7690	67519	67519	24547	24547
15. A/C Maint Hanger 77	C	636	636	8833	8833	0	0	0	0
16. Comp Med/Dent Clinic 77	VC	1347	1347	9912	9912	1616460	1616460	IP	-

COMPILED RESEARCH DATA

#1 Job Description Year Designed Year Constructed	#2 Complexity	#3 A/E costs (000)	#4 adj A/E costs	#5 Const costs (000)	#6 adj Const costs	#7 A/E lia	#8 adj A/E lia	#9 Set amt	#10 adj set amt
17. Base Engr Maint Fac 77	NC	13	13	3524	3524	100000	100000	0	0
18. Op Training Bldg Add 77	C	147	147	1945	1945	0	0	0	0
19. Oil Spill Prev Fac 77	C	352	352	1774	1774	115896	115896	5874	5874
20. Salt Wtr Sys Imprv 77D 81C	C	374	374	3206	2853	211921	188610	IP	-
21. SIMA Fac First Incre 77	C	561	561	5158	5158	0	0	0	0
22. Med/Den Clinic 77	VC	766	766	7947	7947	132298	132298	IP	-
23. Alter/Addn Br Hosp 77D 78C	C	48	48	452	398	0	0	0	0
24. Industrial Waste Fac 77	C	723	723	4300	4300	13498	13498	IP	-
25. Pipe & Boiler Shop 77	VC	1349	1349	20566	20566	4950	4950	IP	-
26. Steam Plant 77D 81C	VC	10156	10156	5500	4896	37038	24064	IP	-
27. Barracks 77	NC	412	412	6882	6882	100000	100000	100000	100000
28. SRB Fac 78	C	1539	1354	8686	7644	4228	3720	0	0
29. Industrial Sec Fence 78	NC	30	26	364	320	35000	30800	7800	6864
30. Helo Escape Train Fac 78	C	74	65	1087	957	0	0	0	0
31. Family Housing Repair 78	NC	414	364	36124	31789	0	0	0	0
32. Pier Improvements 78	C	418	368	4062	3575	84858	74675	72433	63741

COMPILED RESEARCH DATA

#1 Job Description Year Designed Year Constructed	#2 Complexity	#3 A/E costs (000)	#4 adj A/E costs	#5 Const costs (000)	#6 adj Const costs	#7 A/E lia	#8 adj A/E lia	#9 Set amt	#10 adj set amt
33. Weap Sys Sup Fac 79	C	435	361	4729	3925	10275	8528	IP	-
34. Flight Simulator Bldg 79	C	515	427	2539	2107	13470	11180	IP	-
35. Barracks 79	NC	282	234	4415	3664	195182	162001	IP	-
36. Com/Nex Complex 79	NC	664	551	9309	7726	107961	89608	IP	-
37. Elk Hills Tank Farm 80	C	820	763	5558	4613	18809	15611	5000	4150
38. Base Maint Fac 80	NC	204	190	2222	2066	5046	4693	2023	1881
39. Orgn Maint Fac Impro 80	C	337	313	6224	5788	95658	88962	IP	-
40. Operational Train Fac 80	C	379	352	3977	3699	44103	41016	IP	-
41. Barracks 80	NC	525	488	5861	5451	43899	40826	IP	-
42. Operational Train Fac 80	C	481	447	4382	4075	108732	101121	14500	13485
43. Child Care Center 80D 83C	NC	190	177	1925	1386	23944	17240	23944	17240
44. Adv Lghtwt Torp Shop 80	C	624	580	7200	6692	100000	93000	0	0
45. Repair Housing 80	NC	2010	1869	8585	7984	13514	12568	IP	-
46. Tac Veh Maint Shop 80	NC	281	261	2684	2496	0	0	0	0
47. Aircraft Maint Hgr 80	C	112	104	7049	6556	0	0	0	0
48. Rpr Piers 10 & 11 80	C	75	70	1084	1008	0	0	0	0

COMPILED RESEARCH DATA

#1 Job Description Year Designed Year Constructed	#2 Complexity	#3 A/E costs (000)	#4 adj A/E costs	#5 Const costs (000)	#6 adj Const costs	#7 A/E lia	#8 adj A/E lia	#9 Set amt	#10 adj set amt
49. Elect Distribution Proj 80	C	79	73	1050	977	3130	2911	700	651
50. Rpr Gateway Roofs 80	C	1162	1082	4199	3905	49106	45669	IP	-
51. Int Maint Fac 80D 81C	C	336	312	1875	1669	31097	27676	IP	-
52. Emergency Pwr Lift 80	NC	4	4	144	120	3710	3079	0	0
53. Data Processing Ctr 80	NC	446	415	4950	4604	10033	9331	0	0
54. Mission Ctrl Complex 80	VC	786	731	5538	5150	95248	88581	IP	-
55. Operational Train Fac 81	C	125	111	732	651	5000	4450	0	0
56. Applied Inst Bldg 81	NC	473	421	3214	2860	22839	20327	11000	9790
57. Barracks 81	NC	967	861	13780	12264	84247	74980	IP	-
58. Barracks 81	NC	469	417	4053	3607	1131	1007	500	445
59. Nex Complex 81	NC	168	150	2144	1908	28858	25684	IP	-
60. Bowling Alley 81D 82C	NC	29	26	170	153	1794	1615	641	577
61. Reroof Bldgs 81	NC	5	4	1086	967	82195	73154	IP	-
62. Engr Lab 81	C	555	494	5243	4666	700	623	IP	-
63. Rpr Hanger Doors 81	C	86	77	879	791	7278	6551	1000	900
64. Dry Dock Mooring 81	VC	1254	1116	15824	14083	62400	55536	IP	-

COMPILED RESEARCH DATA

#1 Job Description Year Designed Year Constructed	#2 Complexity	#3 A/E costs (000)	#4 adj A/E costs	#5 Const costs (000)	#6 adj Const costs	#7 A/E lia	#8 adj A/E lia	#9 Set amt	#10 adj set amt
65. Barracks 81	NC	325	289	5545	4935	6127	5453	IP	-
66. Barracks 81	NC	1282	1141	8990	8001	138826	123555	IP	-
67. Applied instr Bldg 81	NC	473	421	1952	1737	5797	5159	1750	1558
68. Utility Plant 81	C	1679	1494	2927	2634	162260	146034	IP	-
69. Rpr Control/Telemet 81	C	68	61	574	511	3425	3048	3205	2852
70. Alt Sat Cont Fac 81D 83C	VC	1107	985	1588	1143	67397	48526	IP	-
71. Child Care Center 81	NC	223	198	952	847	3098	2757	1648	1467
72. Ocean Systems Lab 81	C	703	626	4722	4203	6166	5488	IP	-
73. Child Care Center 81	NC	94	84	695	619	2743	2441	IP	-
74. Dinning Fac Mod 81	C	176	157	1788	1591	8284	7373	IP	-
75. Barracks 81	NC	459	409	5131	4567	10015	8913	IP	-
76. Dining Fac 81	NC	120	107	960	854	22150	19714	IP	-
77. Trident Motor test Fac 81	VC	2379	2117	6844	6091	224403	199719	IP	-
78. Cold Storage Whse 81	C	104	93	800	712	230000	204700	0	0
79. Roof Repairs 82	NC	177	159	97	87	0	0	0	0
80. LCAC Complex 82D 83C	VC	3814	3433	7499	5399	24334	17520	IP	-

COMPILED RESEARCH DATA

#1 Job Description Year Designed Year Constructed	#2 Complexity	#3 A/E costs (000)	#4 adj A/E costs	#5 Const costs (000)	#6 adj Const costs	#7 A/E lia	#8 adj A/E lia	#9 Set amt	#10 adj set amt
81. Elect/Comm Shop 82	C	237	213	2295	2066	1522	1370	IP	-
82. Guided Missile Lab 82	C	859	773	6166	5549	851484	766336	IP	-
83. Barracks 82	NC	524	472	1455	1295	71414	63558	0	0
84. Parachute Rpr Shop 82	C	208	187	1549	1394	6623	5961	IP	-
85. Storm Drain System 82D 83C	NC	120	108	185	133	3000	2160	IP	-
86. Rpr Elect Service 82D 83C	C	75	68	57	41	0	0	0	0
87. Racquetball Courts 82	NC	213	192	179	161	8000	7200	IP	-
88. Addn To Aeromedical 82	C	89	80	779	701	1689	1520	IP	-
89. Maint Hanger 83	C	729	525	5240	3773	13344	9608	IP	-
90. Training bldg 83D 84C	C	90	65	982	658	2136	1431	480	322
91. Radar Fac Mod 84	C	78	52	779	522	27617	18503	IP	-

APPENDIX B

NEW CONSTRUCTION INDEX*

year	indix	100/ indix	correction factor
75	66	100/66 =	1.52
76	79	100/79 =	1.27
77	100	100/100 =	1.00
78	114	100/114 =	.88
79	121	100/121 =	.83
80	108	100/108 =	.93
81	112	100/112 =	.89
82	111	100/111 =	.90
83	138	100/138 =	.72
84	150	100/150 =	.67

* Data from ref. 10 and 11

APPENDIX C

REGRESSION ON NOT COMPLEX PROJECTS

COLUMN
C1 NUMERICAL LISTING OF THE PROJECTS
C2 THE A/E COSTS IN THOUSANDS
C3 THE CONSTRUCTION COSTS IN THOUSANDS
C4 A/E LIABILITY COSTS
C5 THE A/E COSTS
C6 THE CONSTRUCTION COSTS

```
MTB > let c5 = 1000*c2
MTB > let c6 = 1000*c3
MTB > print c1-c6
```

ROW	C1	C2	C3	C4	C5	C6
1	1	95	48	0	95000	48000
2	2	116	584	3520	116000	584000
3	3	250	6210	0	250000	6210000
4	4	166	3180	0	166000	3180000
5	5	13	3524	100000	13000	3524000
6	6	412	6882	100000	412000	6882000
7	7	26	320	30800	26000	320000
8	8	364	31789	0	364000	31788992
9	9	234	3664	162001	234000	3664000
10	10	551	7726	89608	551000	7726000
11	11	190	2066	4693	190000	2066000
12	12	488	5451	40826	488000	5451000
13	13	177	1386	17240	177000	1386000
14	14	1869	7984	12568	1869000	7984000
15	15	261	2496	0	261000	2496000
16	16	4	120	3079	4000	120000
17	17	415	4604	9331	415000	4604000
18	18	421	2860	20327	421000	2860000
19	19	861	12264	74980	861000	12264000
20	20	417	3607	1007	417000	3607000
21	21	150	1908	25684	150000	1908000
22	22	26	153	1615	26000	153000
23	23	4	967	73154	4000	967000
24	24	289	4935	5453	289000	4935000
25	25	1141	8001	123555	1141000	8001000
26	26	421	1737	5159	421000	1737000
27	27	198	847	2757	198000	847000
28	28	84	619	2441	84000	619000
29	29	409	4567	8913	409000	4567000
30	30	107	854	19714	107000	854000
31	31	159	87	0	159000	87000
32	32	472	1295	63558	472000	1295000
33	33	108	133	2160	108000	133000
34	34	192	161	7200	192000	161000

```
MTB > regr c4 1 c5
```

The regression equation is
C4 = 21366 + 0.0257 C5

Predictor	Coef	Stdev	t-ratio
Constant	21366	9725	2.20
C5	0.02569	0.02003	1.28

s = 41998 R-sq = 4.9% R-sq(adj) = 1.9%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	1	2900965120	2900965120
Error	32	56441643008	1763801344
Total	33	59342606336	

```
Unusual Observations
Obs.       C5         C4         Fit  Stdev.Fit  Residual   St.Resid
  9    234000     162001       27377       7435    134624      3.26R
 14   1869000      12568       69380      31733    -56812     -2.07RX
 25   1141000     123555       50678      17841     72877      1.92 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > hist c4

Histogram of C4   N = 34

Midpoint   Count
       0      19  *******************
   20000       5  *****
   40000       2  **
   60000       1  *
   80000       3  ***
  100000       2  **
  120000       1  *
  140000       0
  160000       1  *

MTB > let c10 = sqrt(c4)
MTB > hist c10

Histogram of C10   N = 34

Midpoint   Count
       0       6  ******
      50      10  **********
     100       4  ****
     150       4  ****
     200       2  **
     250       3  ***
     300       3  ***
     350       1  *
     400       1  *

MTB > regr c10 1 c5

The regression equation is
C10 = 102 +0.000082 C5

Predictor        Coef          Stdev      t-ratio
Constant       101.86          26.52         3.84
C5         0.00008192     0.00005463         1.50

s = 114.5       R-sq = 6.6%      R-sq(adj) = 3.6%

Analysis of Variance

SOURCE        DF          SS          MS
Regression     1       29497       29497
Error         32      419770       13118
Total         33      449266

Unusual Observations
Obs.       C5        C10         Fit  Stdev.Fit  Residual   St.Resid
  9    234000      402.5       121.0       20.3     281.5      2.50R
 14   1869000      112.1       255.0       86.5    -142.9     -1.90 X
 25   1141000      351.5       195.3       48.7     156.2      1.51 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.
```

```
MTB > regr c10 1 c6

The regression equation is
C10 = 123 +0.000001 C6

Predictor        Coef          Stdev     t-ratio
Constant       122.97          24.63        4.99
C6         0.00000143     0.00000358        0.40

s = 118.2        R-sq = 0.5%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF          SS           MS
Regression     1        2242         2242
Error         32      447025        13970
Total         33      449266

Unusual Observations
Obs.      C6        C10        Fit  Stdev.Fit   Residual    St.Resid
  8 31788992        0.0      168.5      101.8     -168.5     -2.80RX
  9  3664000      402.5      128.2       20.3      274.3      2.36R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c4 1 c6

The regression equation is
C4 = 25973 + 0.00096 C6

Predictor        Coef          Stdev     t-ratio
Constant        25973           8898        2.92
C6           0.000964       0.001292        0.75

s = 42694        R-sq = 1.7%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF           SS            MS
Regression     1   1014430976    1014430976
Error         32  58328178688    1822755584
Total         33  59342606336

Unusual Observations
Obs.      C6         C4        Fit  Stdev.Fit   Residual    St.Resid
  8 31788992          0      56624      36766     -56624     -2.61RX
  9  3664000     162001      29506       7329     132495      3.15R
 25  8001000     123555      33687       9030      89868      2.15R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > hist c5

Histogram of C5   N = 34

Midpoint   Count
       0       7  *******
  200000      14  **************
  400000       9  *********
  600000       1  *
  800000       1  *
 1000000       0
 1200000       1  *
 1400000       0
 1600000       0
 1800000       1  *
```

```
MTB > hist c6

Histogram of C6   N = 34

 Midpoint   Count
        0      18  ******************
  5000000      11  ***********
 10000000       4  ****
 15000000       0
 20000000       0
 25000000       0
 30000000       1  *

MTB > let c11 =1/c5
MTB > hist c11

Histogram of C11   N = 34

Midpoint   Count
 0.00000      27  ***************************
 0.00002       2  **
 0.00004       2  **
 0.00006       0
 0.00008       1  *
 0.00010       0
 0.00012       0
 0.00014       0
 0.00016       0
 0.00018       0
 0.00020       0
 0.00022       0
 0.00024       0
 0.00026       2  **

MTB > let c12 = logt(c5)
MTB > hist c12

Histogram of C12   N = 34

Midpoint   Count
     3.6       2  **
     4.0       1  *
     4.4       2  **
     4.8       2  **
     5.2      12  ************
     5.6      12  ************
     6.0       2  **
     6.4       1  *

MTB > let c13 = sqrt(c5)
MTB > hist c13

Histogram of C13   N = 34

Midpoint   Count
       0       2  **
     200       4  ****
     400      12  ************
     600      12  ************
     800       1  *
    1000       2  **
    1200       0
    1400       1  *
```

```
MTB > let c15 = 1/ c6
MTB > hist c15

Histogram of C15   N = 34

Midpoint   Count
0.000000      22  **********************
0.000002       5  *****
0.000004       1  *
0.000006       2  **
0.000008       2  **
0.000010       0
0.000012       1  *
0.000014       0
0.000016       0
0.000018       0
0.000020       1  *

MTB > let c16 = logt(c6)
MTB > hist c16

Histogram of C16   N = 34

Midpoint   Count
     4.8       2  **
     5.2       4  ****
     5.6       3  ***
     6.0       5  *****
     6.4       9  *********
     6.8       9  *********
     7.2       1  *
     7.6       1  *

MTB > let c17 = sqrt(c6)
MTB > hist c17

Histogram of C17   N = 34

Midpoint   Count
       0       1  *
     500       6  ******
    1000       7  *******
    1500       5  *****
    2000       7  *******
    2500       3  ***
    3000       3  ***
    3500       1  *
    4000       0
    4500       0
    5000       0
    5500       1  *
```

```
MTB > regr c10 1 c13

The regression equation is
C10 = 81.0 + 0.0947 C13

Predictor        Coef          Stdev      t-ratio
Constant        81.01          41.69         1.94
C13           0.09466        0.07299         1.30

s = 115.5       R-sq = 5.0%       R-sq(adj) = 2.0%

Analysis of Variance

SOURCE        DF          SS           MS
Regression     1       22431        22431
Error         32      426836        13339
Total         33      449266

Unusual Observations
Obs.      C13        C10        Fit  Stdev.Fit   Residual    St.Resid
  5       114      316.2       91.8       34.6      224.4       2.04R
  9       484      402.5      126.8       19.9      275.7       2.42R
 14      1367      112.1      210.4       66.1      -98.3      -1.04 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c10 1 c17

The regression equation is
C10 = 87.4 + 0.0251 C17

Predictor        Coef          Stdev      t-ratio
Constant        87.40          35.16         2.49
C17           0.02514        0.01778         1.41

s = 115.0       R-sq = 5.9%       R-sq(adj) = 2.9%

Analysis of Variance

SOURCE        DF          SS           MS
Regression     1       26428        26428
Error         32      422838        13214
Total         33      449266

Unusual Observations
Obs.      C17        C10        Fit  Stdev.Fit   Residual    St.Resid
  8      5638        0.0      229.1       73.8     -229.1      -2.60RX
  9      1914      402.5      135.5       20.3      267.0       2.36R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c10 2 c13 c17

The regression equation is
C10 = 74.6 + 0.0504 C13 + 0.0175 C17

Predictor        Coef          Stdev      t-ratio
Constant        74.57          42.79         1.74
C13           0.05038        0.09350         0.54
C17           0.01751        0.02288         0.77

s = 116.2       R-sq = 6.8%       R-sq(adj) = 0.7%
```

Analysis of Variance

SOURCE	DF	SS	MS
Regression	2	30352	15176
Error	31	418914	13513
Total	33	449266	

SOURCE	DF	SEQ SS
C13	1	22431
C17	1	7922

Unusual Observations

Obs.	C13	C10	Fit	Stdev.Fit	Residual	St.Resid
8	603	0.0	203.7	88.3	-203.7	-2.69RX
9	484	402.5	132.5	21.3	270.0	2.36R
14	1367	112.1	192.9	70.4	-80.8	-0.87 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

```
MTB > plot c4 c5

        -
        -       *  #9
  150000+
        -
C4      -
        -                                  *  #25
        -
  100000+ *           *
        -                *
        -
        - *                        *
        -             *
   50000+
        -              *
        -  *  *
        -    * *      *
        -      *  *   3                                        *  #14
       0+ ***3 3*2  * *
          +---------+---------+---------+---------+---------+------C5
          0    350000    700000   1050000   1400000   1750000
MTB > plot c4 c6

        -
        -      *
  150000+
        -
C4      -
        -             *
        -
  100000+      *    *
        -             *
        -
        -   *                 *
        -   *
   50000+
        -         *
        -  * *
        -  **  *
        - *  *    3    *
       0+ 53 ****   *                                          *  #8
          +---------+---------+---------+---------+---------+------C6
          0   6000000  12000000  18000000  24000000  30000000
```

```
MTB > delete 25 c1-c6
MTB > delete 14 c1-c6
MTB > delete 9 c1-c6
MTB > delete 8 c1-c6
MTB > print c1-c6
 ROW     C1      C2        C3         C4         C5          C6

   1      1      95        48          0      95000       48000
   2      2     116       584       3520     116000      584000
   3      3     250      6210          0     250000     6210000
   4      4     166      3180          0     166000     3180000
   5      5      13      3524     100000      13000     3524000
   6      6     412      6882     100000     412000     6882000
   7      7      26       320      30800      26000      320000
   8     10     551      7726      89608     551000     7726000
   9     11     190      2066       4693     190000     2066000
  10     12     488      5451      40826     488000     5451000
  11     13     177      1386      17240     177000     1386000
  12     15     261      2496          0     261000     2496000
  13     16       4       120       3079       4000      120000
  14     17     415      4604       9331     415000     4604000
  15     18     421      2860      20327     421000     2860000
  16     19     861     12264      74980     861000    12264000
  17     20     417      3607       1007     417000     3607000
  18     21     150      1908      25684     150000     1908000
  19     22      26       153       1615      26000      153000
  20     23       4       967      73154       4000      967000
  21     24     289      4935       5453     289000     4935000
  22     26     421      1737       5159     421000     1737000
  23     27     198       847       2757     198000      847000
  24     28      84       619       2441      84000      619000
  25     29     409      4567       8913     409000     4567000
  26     30     107       854      19714     107000      854000
  27     31     159        87          0     159000       87000
  28     32     472      1295      63558     472000     1295000
  29     33     108       133       2160     108000      133000
  30     34     192       161       7200     192000      161000

MTB > let c20 = sqrt(c4)
MTB > hist c20

Histogram of C20   N = 30

Midpoint   Count
       0       5  *****
      50      10  **********
     100       3  ***
     150       4  ****
     200       2  **
     250       3  ***
     300       3  ***

MTB > regr c4 1 c5

The regression equation is
C4 = 10380 + 0.0537 C5

Predictor       Coef         Stdev     t-ratio
Constant       10380          9220        1.13
C5           0.05371       0.02901        1.85

s = 31306       R-sq = 10.9%      R-sq(adj) = 7.7%

Analysis of Variance

SOURCE        DF            SS            MS
Regression     1    3359245824    3359245824
Error         28   27441987584     980070912
Total         29   30801231872
```

Unusual Observations

Obs.	C5	C4	Fit	Stdev.Fit	Residual	St.Resid
5	13000	100000	11078	8927	88922	2.96R
6	412000	100000	32507	7411	67493	2.22R
16	861000	74980	56621	18640	18359	0.73 X
20	4000	73154	10594	9129	62560	2.09R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c20 1 c5

The regression equation is
C20 = 72.5 +0.000178 C5

Predictor	Coef	Stdev	t-ratio
Constant	72.53	28.75	2.52
C5	0.00017769	0.00009046	1.96

s = 97.62 R-sq = 12.1% R-sq(adj) = 9.0%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	1	36771	36771
Error	28	266839	9530
Total	29	303610	

Unusual Observations

Obs.	C5	C20	Fit	Stdev.Fit	Residual	St.Resid
5	13000	316.2	74.8	27.8	241.4	2.58R
16	861000	273.8	225.5	58.1	48.3	0.62 X
20	4000	270.5	73.2	28.5	197.2	2.11R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c4 1 c6

The regression equation is
C4 = 7927 + 0.00583 C6

Predictor	Coef	Stdev	t-ratio
Constant	7927	7229	1.10
C6	0.005827	0.001846	3.16

s = 28486 R-sq = 26.2% R-sq(adj) = 23.6%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	1	8081002496	8081002496
Error	28	22720229376	811436544
Total	29	30801231872	

Unusual Observations

Obs.	C6	C4	Fit	Stdev.Fit	Residual	St.Resid
5	3524000	100000	28460	5409	71539	2.56R
16	12264000	74980	79387	18374	-4407	-0.20 X
20	967000	73154	13561	6125	59593	2.14R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

```
MTB > regr c20 1 c6

The regression equation is
C20 = 71.7 +0.000017 C6

Predictor        Coef           Stdev      t-ratio
Constant        71.69           23.40         3.06
C6         0.00001660      0.00000598         2.78

s = 92.19       R-sq = 21.6%     R-sq(adj) = 18.8%

Analysis of Variance

SOURCE        DF          SS          MS
Regression     1       65626       65626
Error         28      237984        8499
Total         29      303610

Unusual Observations
Obs.       C6        C20        Fit  Stdev.Fit   Residual   St.Resid
  5   3524000      316.2      130.2       17.5      186.0      2.06R
 16  12264000      273.8      275.3       59.5       -1.5     -0.02 X
 20    967000      270.5       87.7       19.8      182.7      2.03R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > let c21 = sqrt(c5)
MTB > hist c5

Histogram of C5   N = 30

Midpoint   Count
       0       5  *****
  100000       5  *****
  200000       7  *******
  300000       3  ***
  400000       6  ******
  500000       2  **
  600000       1  *
  700000       0
  800000       0
  900000       1  *

MTB > hist c21

Histogram of C21   N = 30

Midpoint   Count
     100       3  ***
     200       2  **
     300       5  *****
     400       7  *******
     500       3  ***
     600       6  ******
     700       3  ***
     800       0
     900       1  *

MTB > regr c20 1 c21

The regression equation is
C20 = 74.8 + 0.0930 C21

Predictor        Coef           Stdev      t-ratio
Constant        74.80           43.90         1.70
C21           0.09300         0.08790         1.06

s = 102.1       R-sq = 3.8%      R-sq(adj) = 0.4%
```

```
Analysis of Variance

SOURCE        DF          SS          MS
Regression     1       11670       11670
Error         28      291940       10426
Total         29      303610

Unusual Observations
Obs.     C21       C20         Fit  Stdev.Fit   Residual    St.Resid
  5      114     316.2        85.4       35.1      230.8       2.41R
 16      928     273.8       161.1       45.8      112.7       1.24 X
 20       63     270.5        80.7       38.9      189.8       2.01R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > let c22 = sqrt(c6)
MTB > hist c6

Histogram of C6   N = 30

 Midpoint   Count
        0       7  *******
  1000000       7  *******
  2000000       4  ****
  3000000       2  **
  4000000       2  **
  5000000       4  ****
  6000000       1  *
  7000000       1  *
  8000000       1  *
  9000000       0
 10000000       0
 11000000       0
 12000000       1  *

MTB > hist c22

Histogram of C22   N = 30

Midpoint   Count
       0       1  *
     500       6  ******
    1000       7  *******
    1500       5  *****
    2000       6  ******
    2500       3  ***
    3000       1  *
    3500       1  *

MTB > regr c20 1 c22

The regression equation is
C20 = 39.8 + 0.0544 C22

Predictor       Coef        Stdev     t-ratio
Constant       39.83        32.99        1.21
C22          0.05439      0.02000        2.72

s = 92.62       R-sq = 20.9%     R-sq(adj) = 18.1%

Analysis of Variance

SOURCE        DF          SS          MS
Regression     1       63423       63423
Error         28      240187        8578
Total         29      303610
```

```
Unusual Observations
Obs.      C22         C20        Fit Stdev.Fit   Residual    St.Resid
 16      3502       273.8      230.3      45.0       43.5      0.54 X

X denotes an obs. whose X value gives it large influence.

MTB > plot c4 c6

        -               *             *
        -
   90000+                                *
        -
C4      -
        -     *                                            *  #16
        -      *
   60000+
        -
        -
        -                       *
        -
   30000+  *
        -         *
        -    *  *    *
        -                   *
        - ***    **         *  *
       0+ 22**       *  **          *
          +---------+---------+---------+---------+---------+------C6
          0   2500000   5000000   7500000  10000000  12500000
MTB > plot c4 c5
        -  *  #5                      *
        -
   90000+                                   *
        -
C4      -
        - *  #20                                               *
        -                               *
   60000+
        -
        -
        -                                *
        -
   30000+   *
        -          *
        -        *   *                *
        -                             *
        - *      *    2     *         2
       0+   *  ***   2 *   2          *
          +---------+---------+---------+---------+---------+------C5
          0    160000    320000    480000    640000    800000
```

```
MTB > delete 20 c1-c6
MTB > delete 16 c1-c6
MTB > delete 5 c1-c6
MTB > print c1-c6
 ROW     C1     C2     C3       C4       C5        C6

   1      1     95     48        0    95000     48000
   2      2    116    584     3520   116000    584000
   3      3    250   6210        0   250000   6210000
   4      4    166   3180        0   166000   3180000
   5      6    412   6882   100000   412000   6882000
   6      7     26    320    30800    26000    320000
   7     10    551   7726    89608   551000   7726000
   8     11    190   2066     4693   190000   2066000
   9     12    488   5451    40826   488000   5451000
  10     13    177   1386    17240   177000   1386000
  11     15    261   2496        0   261000   2496000
  12     16      4    120     3079     4000    120000
  13     17    415   4604     9331   415000   4604000
  14     18    421   2860    20327   421000   2860000
  15     20    417   3607     1007   417000   3607000
  16     21    150   1908    25684   150000   1908000
  17     22     26    153     1615    26000    153000
  18     24    289   4935     5453   289000   4935000
  19     26    421   1737     5159   421000   1737000
  20     27    198    847     2757   198000    847000
  21     28     84    619     2441    84000    619000
  22     29    409   4567     8913   409000   4567000
  23     30    107    854    19714   107000    854000
  24     31    159     87        0   159000     87000
  25     32    472   1295    63558   472000   1295000
  26     33    108    133     2160   108000    133000
  27     34    192    161     7200   192000    161000

MTB > let c30 = sqrt(c4)
MTB > hist c30

Histogram of C30   N = 27

Midpoint   Count
       0       5  *****
      50      10  **********
     100       3  ***
     150       4  ****
     200       2  **
     250       1  *
     300       2  **

MTB > regr c4 1 c5

The regression equation is
C4 = - 4741 + 0.0898 C5

Predictor        Coef         Stdev     t-ratio
Constant        -4741          8193       -0.58
C5            0.08981       0.02814        3.19

s = 23098        R-sq = 29.0%     R-sq(adj) = 26.1%

Analysis of Variance

SOURCE       DF          SS           MS
Regression    1   5435138048   5435138048
Error        25  13337370624    533494784
Total        26  18772508672
```

```
Unusual Observations
Obs.      C5          C4          Fit  Stdev.Fit   Residual    St.Resid
  5    412000      100000       32260       6477      67740       3.06R
  7    551000       89608       44744       9700      44864       2.14R

R denotes an obs. with a large st. resid.

MTB > regr c30 1 c5

The regression equation is
C30 = 27.8 +0.000287 C5

Predictor         Coef          Stdev      t-ratio
Constant         27.79          27.52         1.01
C5          0.00028688     0.00009453         3.03

s = 77.60        R-sq = 26.9%     R-sq(adj) = 24.0%

Analysis of Variance

SOURCE        DF          SS          MS
Regression     1       55458       55458
Error         25      150526        6021
Total         26      205985

Unusual Observations
Obs.      C5         C30          Fit  Stdev.Fit   Residual    St.Resid
  5    412000       316.2        146.0       21.8      170.2       2.29R

R denotes an obs. with a large st. resid.

MTB > let c31 = sqrt(c5)
MTB > hist c31

Histogram of C31    N = 27

Midpoint    Count
     100        1  *
     200        2  **
     300        5  *****
     400        7  *******
     500        3  ***
     600        6  ******
     700        3  ***

MTB > regr c30 1 c31

The regression equation is
C30 = - 0.6 + 0.214 C31

Predictor         Coef          Stdev      t-ratio
Constant         -0.63          43.71        -0.01
C31        0.21366        0.08837         2.42

s = 81.72        R-sq = 19.0%     R-sq(adj) = 15.7%
```

```
Analysis of Variance

SOURCE        DF          SS          MS
Regression     1       39037       39037
Error         25      166948        6678
Total         26      205985

Unusual Observations
Obs.      C31       C30        Fit Stdev.Fit   Residual   St.Resid
  5       642     316.2      136.5      22.4      179.7      2.29R
 12        63      55.5       12.9      38.5       42.6      0.59 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c4 1 c6

The regression equation is
C4 = 2402 + 0.00617 C6

Predictor        Coef         Stdev     t-ratio
Constant         2402          6474        0.37
C6           0.006173      0.001955        3.16

s = 23169        R-sq = 28.5%     R-sq(adj) = 25.7%

Analysis of Variance

SOURCE        DF          SS          MS
Regression     1  5352509440  5352509440
Error         25 13419999232   536799744
Total         26 18772508672

Unusual Observations
Obs.       C6        C4        Fit Stdev.Fit   Residual   St.Resid
  5   6882000    100000      44884      9829      55116      2.63R
  7   7726000     89608      50094     11324      39514      1.95 X
 25   1295000     63558      10396      4956      53162      2.35R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > hist c6

Histogram of C6   N = 27

 Midpoint   Count
        0       7  *******
  1000000       6  ******
  2000000       4  ****
  3000000       2  **
  4000000       1  *
  5000000       4  ****
  6000000       1  *
  7000000       1  *
  8000000       1  *

MTB > let c32 = sqrt(c6)
MTB > hist c32

Histogram of C32   N = 27

Midpoint   Count
     400       7  *******
     800       4  ****
    1200       4  ****
    1600       4  ****
    2000       3  ***
    2400       3  ***
    2800       2  **
```

```
MTB > let c33 = logt(c6)
MTB > hist c33

Histogram of C33   N = 27

Midpoint   Count
     4.6       1  *
     4.8       0
     5.0       2  **
     5.2       3  ***
     5.4       0
     5.6       1  *
     5.8       2  **
     6.0       2  **
     6.2       4  ****
     6.4       3  ***
     6.6       5  *****
     6.8       4  ****

MTB > regr c4 1 c33

The regression equation is
C4 = - 81832 + 16367 C33

Predictor        Coef          Stdev     t-ratio
Constant       -81832          45522       -1.80
C33             16367           7479        2.19

s = 25103        R-sq = 16.1%     R-sq(adj) = 12.7%

Analysis of Variance

SOURCE        DF           SS            MS
Regression     1   3017996800    3017996800
Error         25  15754510336     630180352
Total         26  18772504576

Unusual Observations
Obs.      C33         C4         Fit Stdev.Fit   Residual     St.Resid
  5      6.84     100000       30080      7606      69920        2.92R
  7      6.89      89608       30903      7899      58705        2.46R

R denotes an obs. with a large st. resid.

MTB > regr c30 1 c33

The regression equation is
C30 = - 233 + 54.7 C33

Predictor        Coef          Stdev     t-ratio
Constant       -232.9          150.6       -1.55
C33             54.67          24.73        2.21

s = 83.02        R-sq = 16.3%     R-sq(adj) = 13.0%

Analysis of Variance

SOURCE        DF           SS            MS
Regression     1        33668         33668
Error         25       172316          6893
Total         26       205985

Unusual Observations
Obs.      C33        C30         Fit Stdev.Fit   Residual     St.Resid
  5      6.84      316.2       140.9      25.2      175.3        2.22R

R denotes an obs. with a large st. resid.
```

```
MTB > regr c4 2 c5 c6

The regression equation is
C4 = - 3932 + 0.0526 C5 + 0.00345 C6

Predictor        Coef          Stdev     t-ratio
Constant        -3932           8154       -0.48
C5            0.05258        0.04193        1.25
C6           0.003455       0.002904        1.19

s = 22908       R-sq = 32.9%     R-sq(adj) = 27.3%

Analysis of Variance

SOURCE        DF           SS          MS
Regression     2   6177984512  3088992256
Error         24  12594520064   524771584
Total         26  18772504576

SOURCE        DF       SEQ SS
C5             1   5435138048
C6             1    742846976

Unusual Observations
Obs.      C5        C4        Fit Stdev.Fit   Residual    St.Resid
  5   412000    100000      41508     10084      58492       2.84R
 25   472000     63558      25361     12899      38197       2.02R

R denotes an obs. with a large st. resid.

MTB > regr c4 2 c31 c32

The regression equation is
C4 = - 11958 + 35.3 C31 + 9.63 C32

Predictor        Coef          Stdev     t-ratio
Constant       -11958          13191       -0.91
C31             35.33          41.54        0.85
C32             9.628          9.451        1.02

s = 24319       R-sq = 24.4%     R-sq(adj) = 18.1%

Analysis of Variance

SOURCE        DF           SS          MS
Regression     2   4578418688  2289209344
Error         24  14194089984   591420416
Total         26  18772508672

SOURCE        DF       SEQ SS
C31            1   3964684800
C32            1    613734144

Unusual Observations
Obs.     C31        C4        Fit Stdev.Fit   Residual    St.Resid
  5      642    100000      35979      9205      64021       2.84R
  7      742     89608      41031      9878      48577       2.19R

R denotes an obs. with a large st. resid.

MTB > regr c4 1 c32

The regression equation is
C4 = - 3977 + 15.9 C32

Predictor        Coef          Stdev     t-ratio
Constant        -3977           9220       -0.43
C32            15.850          5.950        2.66

s = 24184       R-sq = 22.1%     R-sq(adj) = 19.0%
```

Analysis of Variance

SOURCE	DF	SS	MS
Regression	1	4150585600	4150585600
Error	25	14621921280	584876800
Total	26	18772504576	

Unusual Observations

Obs.	C32	C4	Fit	Stdev.Fit	Residual	St.Resid
5	2623	100000	37603	8954	62397	2.78R
7	2780	89608	40079	9760	49529	2.24R
25	1138	63558	14060	4804	49498	2.09R

R denotes an obs. with a large st. resid.

MTB > regr c30 1 c32

The regression equation is
C30 = 35.4 + 0.0468 C32

Predictor	Coef	Stdev	t-ratio
Constant	35.36	31.42	1.13
C32	0.04680	0.02028	2.31

s = 82.41   R-sq = 17.6%   R-sq(adj) = 14.3%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	1	36183	36183
Error	25	169802	6792
Total	26	205985	

Unusual Observations

Obs.	C32	C30	Fit	Stdev.Fit	Residual	St.Resid
5	2623	316.2	158.1	30.5	158.1	2.07R
25	1138	252.1	88.6	16.4	163.5	2.02R

R denotes an obs. with a large st. resid.

MTB > plot c4 c5

```
         -                                          *   #5
         -
    90000+                                                        *#7
         -
 C4      -
         -
         -                                                *
    60000+
         -
         -
         -                                                  *
         -
    30000+    *
         -                *
         -            *      *                       *
         -                                           *
         - *           *      2         *           **
        0+    *    * **    **  *    **                *
           +---------+---------+---------+---------+---------+------C5
           0    100000    200000    300000    400000    500000
```

```
MTB > plot c4 c6

         -                                               *  #5
         -
    90000+                                                     *  #7
         -
 C4      -
         -
         -          *
    60000+
         -
         -
         -                            *
         -
    30000+   *
         -              *
         -       *  *         *
         -                              *
         -  2  *       *  *               *  *
       0+ *3  *  *          *   *  *                *
          +---------+---------+---------+---------+---------+------C6
          0    1500000   3000000   4500000   6000000   7500000
MTB > delete 7 c1-c6
MTB > delete 5 c1-c6
MTB > print c1-c6
```

ROW	C1	C2	C3	C4	C5	C6
1	1	95	48	0	95000	48000
2	2	116	584	3520	116000	584000
3	3	250	6210	0	250000	6210000
4	4	166	3180	0	166000	3180000
5	7	26	320	30800	26000	320000
6	11	190	2066	4693	190000	2066000
7	12	488	5451	40826	488000	5451000
8	13	177	1386	17240	177000	1386000
9	15	261	2496	0	261000	2496000
10	16	4	120	3079	4000	120000
11	17	415	4604	9331	415000	4604000
12	18	421	2860	20327	421000	2860000
13	20	417	3607	1007	417000	3607000
14	21	150	1908	25684	150000	1908000
15	22	26	153	1615	26000	153000
16	24	289	4935	5453	289000	4935000
17	26	421	1737	5159	421000	1737000
18	27	198	847	2757	198000	847000
19	28	84	619	2441	84000	619000
20	29	409	4567	8913	409000	4567000
21	30	107	854	19714	107000	854000
22	31	159	87	0	159000	87000
23	32	472	1295	63558	472000	1295000
24	33	108	133	2160	108000	133000
25	34	192	161	7200	192000	161000

```
MTB > regr c4 1 c5

The regression equation is
C4 = 2067 + 0.0397 C5
```

Predictor	Coef	Stdev	t-ratio
Constant	2067	5319	0.39
C5	0.03968	0.01974	2.01

s = 14542   R-sq = 14.9%   R-sq(adj) = 11.2%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	1	854694400	854694400
Error	23	4863979520	211477360
Total	24	5718671360	

```
Unusual Observations
Obs.      C5         C4         Fit  Stdev.Fit   Residual    St.Resid
  5    26000      30800        3098       4897      27702       2.02R
 23   472000      63558       20793       5666      42765       3.19R

R denotes an obs. with a large st. resid.

MTB > let c40 = sqrt(c4)
MTB > hist c40

Histogram of C40   N = 25

Midpoint   Count
       0       5  *****
      40       7  *******
      80       6  ******
     120       1  *
     160       4  ****
     200       1  *
     240       1  *

MTB > regr c40 1 c5

The regression equation is
C40 = 45.0 +0.000160 C5

Predictor        Coef          Stdev     t-ratio
Constant        44.97          23.72        1.90
C5         0.00016045     0.00008803        1.82

s = 64.86       R-sq = 12.6%      R-sq(adj) = 8.8%

Analysis of Variance

SOURCE       DF           SS           MS
Regression    1        13978        13978
Error        23        96766         4207
Total        24       110744

Unusual Observations
Obs.      C5        C40         Fit  Stdev.Fit   Residual    St.Resid
  5    26000      175.5        49.1       21.8      126.4       2.07R
 23   472000      252.1       120.7       25.3      131.4       2.20R

R denotes an obs. with a large st. resid.

MTB > regr c4 1 c6

The regression equation is
C4 = 9881 + 0.00057 C6

Predictor        Coef          Stdev     t-ratio
Constant         9881           4607        2.15
C6           0.000566       0.001675        0.34

s = 15729       R-sq = 0.5%       R-sq(adj) = 0.0%

Analysis of Variance

SOURCE       DF           SS           MS
Regression    1     28279680     28279680
Error        23   5690392576    247408368
Total        24   5718671360

Unusual Observations
Obs.      C6         C4         Fit  Stdev.Fit   Residual    St.Resid
  3  6210000          0       13398       7707     -13398      -0.98 X
 23  1295000      63558       10615       3366      52943       3.45R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.
```

```
MTB > regr c40 1 c6

The regression equation is
C40 = 76.9 +0.000002 C6

Predictor        Coef          Stdev     t-ratio
Constant        76.95          20.29        3.79
C6         0.00000211     0.00000738        0.29

s = 69.27       R-sq = 0.4%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF          SS          MS
Regression     1         391         391
Error         23      110353        4798
Total         24      110744

Unusual Observations
Obs.      C6       C40       Fit Stdev.Fit  Residual    St.Resid
  3  6210000       0.0      90.0      33.9     -90.0     -1.49 X
 23  1295000     252.1      79.7      14.8     172.4      2.55R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > let c41 = sqrt(c5)
MTB > hist c41

Histogram of C41   N = 25

Midpoint   Count
     100       1  *
     200       2  **
     300       5  *****
     400       7  *******
     500       3  ***
     600       5  *****
     700       2  **

MTB > let c42 = sqrt(c6)
MTB > hist c42

Histogram of C42   N = 25

Midpoint   Count
     200       2  **
     400       4  ****
     600       1  *
     800       2  **
    1000       2  **
    1200       2  **
    1400       3  ***
    1600       2  **
    1800       2  **
    2000       0
    2200       3  ***
    2400       2  **

MTB > regr c4 1 c41

The regression equation is
C4 = - 1091 + 27.3 C41

Predictor        Coef          Stdev     t-ratio
Constant        -1091           8306       -0.13
C41             27.34          17.48        1.56

s = 14792       R-sq = 9.6%      R-sq(adj) = 5.7%
```

```
Analysis of Variance

SOURCE        DF           SS            MS
Regression     1    549422336     549422336
Error         23   5169250304     224750000
Total         24   5718671360

Unusual Observations
Obs.       C41        C4        Fit  Stdev.Fit   Residual    St.Resid
 23        687     63558      17691       5215      45867       3.26R

R denotes an obs. with a large st. resid.

MTB > regr c40 1 c41

The regression equation is
C40 = 33.6 + 0.107 C41

Predictor        Coef          Stdev     t-ratio
Constant        33.56          36.94        0.91
C41           0.10748        0.07777        1.38

s = 66.68        R-sq = 7.7%      R-sq(adj) = 3.7%

Analysis of Variance

SOURCE        DF           SS            MS
Regression     1         8493          8493
Error         23       102251          4446
Total         24       110744

Unusual Observations
Obs.       C41       C40        Fit  Stdev.Fit   Residual    St.Resid
  5        161     175.5       50.9       25.6      124.6       2.02R
 23        687     252.1      107.4       23.2      144.7       2.31R

R denotes an obs. with a large st. resid.

MTB > regr c4 1 c42

The regression equation is
C4 = 7660 + 2.73 C42

Predictor        Coef          Stdev     t-ratio
Constant         7660           6272        1.22
C42             2.734          4.425        0.62

s = 15639        R-sq = 1.6%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF           SS            MS
Regression     1     93355456      93355456
Error         23   5625315328     244578912
Total         24   5718667264

Unusual Observations
Obs.       C42        C4        Fit  Stdev.Fit   Residual    St.Resid
 23       1138     63558      10771       3153      52787       3.45R

R denotes an obs. with a large st. resid.

MTB > regr c40 1 c42

The regression equation is
C40 = 65.8 + 0.0125 C42

Predictor        Coef          Stdev     t-ratio
Constant        65.79          27.58        2.39
C42           0.01252        0.01946        0.64

s = 68.77        R-sq = 1.8%      R-sq(adj) = 0.0%
```

Analysis of Variance

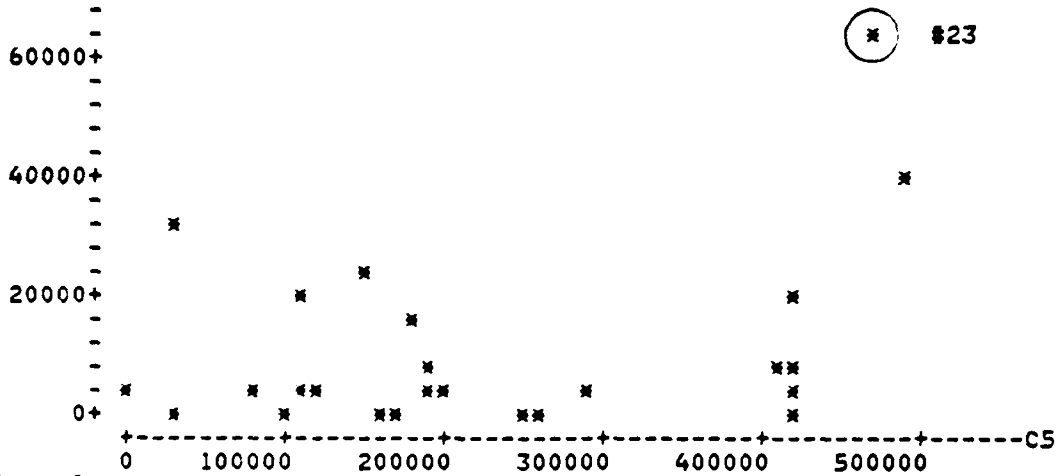
SOURCE	DF	SS	MS
Regression	1	1958	1958
Error	23	108786	4730
Total	24	110744	

Unusual Observations

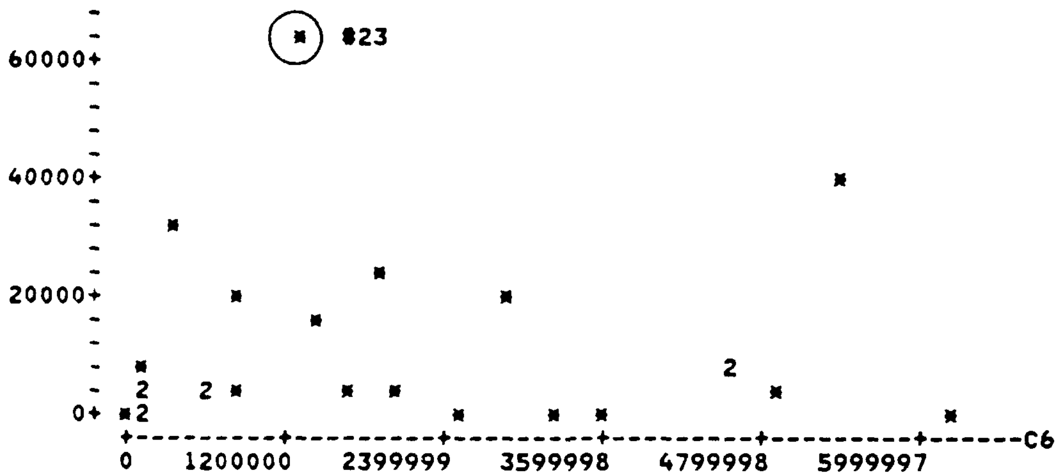
Obs.	C42	C40	Fit	Stdev.Fit	Residual	St.Resid
23	1138	252.1	80.0	13.9	172.1	2.55R

R denotes an obs. with a large st. resid.

MTB > plot c4 c5



MTB > plot c4 c6



```
MTB > delete 23 c1-c6
MTB > print c1-c6
 ROW     C1      C2       C3        C4         C5          C6

   1      1      95       48         0      95000       48000
   2      2     116      584      3520     116000      584000
   3      3     250     6210         0     250000     6210000
   4      4     166     3180         0     166000     3180000
   5      7      26      320     30800      26000      320000
   6     11     190     2066      4693     190000     2066000
   7     12     488     5451     40826     488000     5451000
   8     13     177     1386     17240     177000     1386000
   9     15     261     2496         0     261000     2496000
  10     16       4      120      3079       4000      120000
  11     17     415     4604      9331     415000     4604000
  12     18     421     2860     20327     421000     2860000
  13     20     417     3607      1007     417000     3607000
  14     21     150     1908     25684     150000     1908000
  15     22      26      153      1615      26000      153000
  16     24     289     4935      5453     289000     4935000
  17     26     421     1737      5159     421000     1737000
  18     27     198      847      2757     198000      847000
  19     28      84      619      2441      84000      619000
  20     29     409     4567      8913     409000     4567000
  21     30     107      854     19714     107000      854000
  22     31     159       87         0     159000       87000
  23     33     108      133      2160     108000      133000
  24     34     192      161      7200     192000      161000

MTB > regr c4  1 c5

The regression equation is
C4 = 5212 + 0.0168 C5

Predictor        Coef          Stdev      t-ratio
Constant         5212           4127         1.26
C5            0.01680        0.01602         1.05

s = 11094        R-sq = 4.8%       R-sq(adj) = 0.4%

Analysis of Variance

SOURCE         DF           SS            MS
Regression      1    135394944     135394944
Error          22   2707927296     123087600
Total          23   2843322112

Unusual Observations
Obs.       C5          C4          Fit  Stdev.Fit   Residual     St.Resid
  5     26000       30800         5649       3785      25151        2.41R
  7    488000       40826        13410       4919      27416        2.76R

R denotes an obs. with a large st. resid.

MTB > regr c4 1 c6

The regression equation is
C4 = 6759 + 0.00102 C6

Predictor        Coef          Stdev      t-ratio
Constant         6759           3339         2.02
C6           0.001016       0.001195         0.85

s = 11186        R-sq = 3.2%       R-sq(adj) = 0.0%

Analysis of Variance

SOURCE         DF           SS            MS
Regression      1     90405440      90405440
Error          22   2752916736     125132576
Total          23   2843322112
```

```
Unusual Observations
Obs.      C6          C4         Fit  Stdev.Fit   Residual    St.Resid
  5   320000       30800        7084       3071      23716       2.20R
  7  5451000       40826       12295       4673      28531       2.81R

R denotes an obs. with a large st. resid.

MTB > let c50 = sqrt(c4)
MTB > hist c50

Histogram of C50   N = 24

Midpoint   Count
       0       5  *****
      20       0
      40       4  ****
      60       4  ****
      80       3  ***
     100       2  **
     120       0
     140       3  ***
     160       1  *
     180       1  *
     200       1  *

MTB > regr c50 1 c5

The regression equation is
C50 = 54.6 +0.000090 C5

Predictor        Coef          Stdev      t-ratio
Constant        54.64          21.92         2.49
C5         0.00009015     0.00008509         1.06

s = 58.93        R-sq = 4.9%      R-sq(adj) = 0.5%

Analysis of Variance

SOURCE         DF          SS           MS
Regression      1        3899         3899
Error          22       76409         3473
Total          23       80308

Unusual Observations
Obs.      C5         C50         Fit  Stdev.Fit   Residual    St.Resid
  5    26000       175.5        57.0       20.1      118.5       2.14R

R denotes an obs. with a large st. resid.

MTB > regr c50 1 c6

The regression equation is
C50 = 66.8 +0.000004 C6

Predictor        Coef          Stdev      t-ratio
Constant        66.78          17.91         3.73
C6         0.00000357     0.00000641         0.56

s = 60.00        R-sq = 1.4%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE         DF          SS           MS
Regression      1        1116         1116
Error          22       79192         3600
Total          23       80308

Unusual Observations
Obs.      C6         C50         Fit  Stdev.Fit   Residual    St.Resid
  7  5451000       202.1        86.2       25.1      115.8       2.12R

R denotes an obs. with a large st. resid.
```

```
MTB > let c51 = sqrt(c5)
MTB > hist c51

Histogram of C51   N = 24

Midpoint   Count
     100       1  *
     200       2  **
     300       5  *****
     400       7  *******
     500       3  ***
     600       5  *****
     700       1  *

MTB > regr c50 1 c51

The regression equation is
C50 = 51.2 + 0.0528 C51

Predictor        Coef          Stdev     t-ratio
Constant        51.19          33.77        1.52
C51           0.05283        0.07278        0.73

s = 59.71       R-sq = 2.3%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF          SS          MS
Regression     1        1879        1879
Error         22       78430        3565
Total         23       80308

Unusual Observations
Obs.     C51      C50        Fit Stdev.Fit   Residual    St.Resid
  5      161    175.5       59.7      23.2      115.8       2.11R
  7      699    202.1       88.1      22.9      114.0       2.07R

R denotes an obs. with a large st. resid.

MTB > regr c4 1 c51

The regression equation is
C4 = 4495 + 10.0 C51

Predictor        Coef          Stdev     t-ratio
Constant         4495           6354        0.71
C51             10.02          13.69        0.73

s = 11233       R-sq = 2.4%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF          SS          MS
Regression     1    67520800    67520800
Error         22  2775801600   126172800
Total         23  2843322368

Unusual Observations
Obs.     C51       C4        Fit Stdev.Fit   Residual    St.Resid
  5      161    30800       6110      4368      24690       2.39R
  7      699    40826      11492      4301      29334       2.83R

R denotes an obs. with a large st. resid.
```

```
MTB > let c52 = sqrt(c6)
MTB > hist c52

Histogram of C52   N = 24

Midpoint   Count
     200       2  **
     400       4  ****
     600       1  *
     800       2  **
    1000       2  **
    1200       1  *
    1400       3  ***
    1600       2  **
    1800       2  **
    2000       0
    2200       3  ***
    2400       2  **

MTB > let c53 = logt(c6)
MTB > hist c53

Histogram of C53   N = 24

Midpoint   Count
     4.6       1  *
     4.8       0
     5.0       2  **
     5.2       3  ***
     5.4       0
     5.6       1  *
     5.8       2  **
     6.0       2  **
     6.2       3  ***
     6.4       3  ***
     6.6       5  *****
     6.8       2  **

MTB > regr c4 1 c52

The regression equation is
C4 = 4969 + 3.13 C52

Predictor        Coef          Stdev     t-ratio
Constant         4969           4494        1.11
C52             3.133          3.148        1.00

s = 11121        R-sq = 4.3%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF          SS            MS
Regression     1   122523760     122523760
Error         22  2720798464     123672656
Total         23  2843322112

Unusual Observations
Obs.      C52        C4        Fit  Stdev.Fit   Residual    St.Resid
  5       566     30800       6741       3091      24059       2.25R
  7      2335     40826      12284       4146      28542       2.77R

R denotes an obs. with a large st. resid.

MTB > regr c50 1 c52

The regression equation is
C50 = 57.0 + 0.0138 C52

Predictor        Coef          Stdev     t-ratio
Constant        57.02          24.05        2.37
C52           0.01382        0.01684        0.82

s = 59.51        R-sq = 3.0%      R-sq(adj) = 0.0%
```

Analysis of Variance

SOURCE	DF	SS	MS
Regression	1	2384	2384
Error	22	77924	3542
Total	23	80308	

Unusual Observations

Obs.	C52	C50	Fit	Stdev.Fit	Residual	St.Resid
7	2335	202.1	89.3	22.2	112.8	2.04R

R denotes an obs. with a large st. resid.

MTB > regr c50 2 c51 c52

The regression equation is
C50 = 53.5 + 0.017 C51 + 0.0108 C52

Predictor	Coef	Stdev	t-ratio
Constant	53.47	34.92	1.53
C51	0.0168	0.1173	0.14
C52	0.01079	0.02725	0.40

s = 60.89   R-sq = 3.1%   R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	2	2461	1230
Error	21	77848	3707
Total	23	80308	

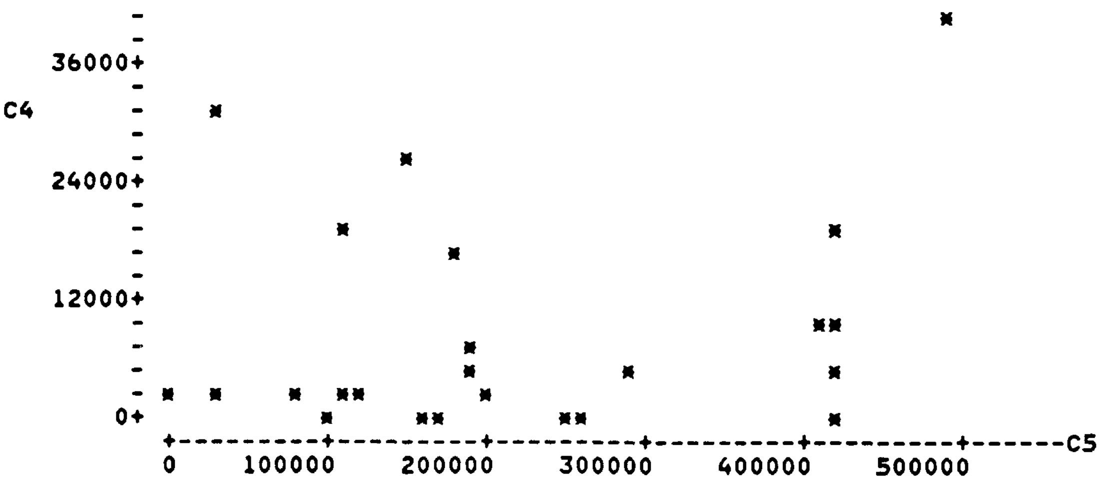
SOURCE	DF	SEQ SS
C51	1	1879
C52	1	582

Unusual Observations

Obs.	C51	C50	Fit	Stdev.Fit	Residual	St.Resid
5	161	175.5	62.3	24.6	113.2	2.03R

R denotes an obs. with a large st. resid.

MTB > plot c4 c5



```
MTB > plot c4 c6
        -                                              *
        -
   36000+
        -
C4      -    *
        -
        -                 *
   24000+
        -
        -        *                *
        -             *
        -
   12000+
        -                                       2
        -  *
        -               *  *                       *
        -  3   2 *
       0+ **                   *     *  *                     *
          +---------+---------+---------+---------+---------+---------+------C6
          0   1200000   2399999   3599998   4799998   5999997
```

APPENDIX D

REGRESSION ON COMPLEX PROJECTS

COLUMN
C1 NUMERICAL LISTING OF THE PROJECTS
C2 THE A/E COSTS IN THOUSANDS
C3 THE CONSTRUCTION COSTS IN THOUSANDS
C4 A/E LIABILITY COSTS
C5 THE A/E COSTS
C6 THE CONSTRUCTION COSTS

```
MTB > let c5 = 1000*c2
MTB > let c6 = 1000*c3
MTB > print c1-c6
```

ROW	C1	C2	C3	C4	C5	C6
1	1	1166	1308	4380	1166000	1308000
2	2	403	3470	0	403000	3470000
3	3	1030	1745	5389	1030000	1745000
4	4	9670	10100	21000	9670000	10100000
5	5	1050	13236	0	1050000	13236000
6	6	14	2426	25500	14000	2426000
7	7	391	5454	12191	391000	5454000
8	8	578	7690	67519	578000	7690000
9	9	636	8833	0	636000	8833000
10	10	147	1945	0	147000	1945000
11	11	352	1774	115896	352000	1774000
12	12	374	2835	188610	374000	2835000
13	13	561	5158	0	561000	5158000
14	14	48	398	0	48000	398000
15	15	723	4300	13498	723000	4300000
16	16	1354	7644	3720	1354000	7644000
17	17	65	957	0	65000	957000
18	18	368	3575	74675	368000	3575000
19	19	361	3925	8528	361000	3925000
20	20	427	2107	11180	427000	2107000
21	21	763	4613	15611	763000	4613000
22	22	313	5788	88962	313000	5788000
23	23	352	3699	41016	352000	3699000
24	24	447	4075	101121	447000	4075000
25	25	580	6692	93000	580000	6692000
26	26	104	6556	0	104000	6556000
27	27	70	1008	0	70000	1008000
28	28	73	977	2911	73000	977000
29	29	1082	3905	45669	1082000	3905000
30	30	312	1669	27676	312000	1669000
31	31	111	651	4450	111000	651000
32	32	494	4666	623	494000	4666000
33	33	77	791	6551	77000	791000
34	34	1494	2634	146034	1494000	2634000
35	35	61	511	3048	61000	511000
36	36	626	4203	5488	626000	4203000
37	37	157	1591	7373	1570[illegible]	1591000
38	38	93	712	204700	93000	712000
39	39	213	2066	1370	213000	2066000
40	40	773	5549	766336	773000	5549000
41	41	187	1394	5961	187000	1394000
42	42	68	41	0	68000	41000
43	43	80	701	1520	80000	701000
44	44	525	3773	9608	525000	3773000
45	45	65	658	1431	65000	658000
46	46	52	522	18503	52000	522000

```
MTB > regr c4 1 c5

The regression equation is
C4 = 45900 + 0.0014 C5

Predictor        Coef          Stdev     t-ratio
Constant        45900          19537        2.35
C5            0.00137        0.01275        0.11

s = 120866       R-sq = 0.0%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE       DF           SS           MS
Regression    1    169121776    169121776
Error        44 642773352448  14608482304
Total        45 642942435328

Unusual Observations
Obs.      C5          C4        Fit  Stdev.Fit   Residual    St.Resid
  4  9670000       21000      59165     116646     -38165     -1.21 X
 40   773000      766336      46961      17916     719375      6.02R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c4 1 c6

The regression equation is
C4 = 32702 + 0.00408 C6

Predictor        Coef          Stdev     t-ratio
Constant        32702          27891        1.17
C6           0.004085       0.006254        0.65

s = 120300       R-sq = 1.0%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE       DF           SS           MS
Regression    1   6175002624   6175002624
Error        44 636767502336  14471987200
Total        45 642942500864


Unusual Observations
Obs.      C6          C4        Fit  Stdev.Fit   Residual    St.Resid
  4 10100000       21000      73960      45258     -52960     -0.48 X
  5 13236000           0      86771      63766     -86771     -0.85 X
 40  5549000      766336      55370      22096     710966      6.01R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > hist c4

Histogram of C4   N = 46

Midpoint    Count
       0       36  ************************************
  100000        7  *******
  200000        2  **
  300000        0
  400000        0
  500000        0
  600000        0
  700000        0
  800000        1  *
```

```
MTB > let c10 = sqrt(c4)
MTB > hist c10

Histogram of C10   N = 46

Midpoint   Count
       0      14  **************
     100      18  ******************
     200       4  ****
     300       6  ******
     400       2  **
     500       1  *
     600       0
     700       0
     800       0
     900       1  *


MTB > regr c10 1 c5

The regression equation is
C10 = 135 +0.000007 C5

Predictor        Coef          Stdev     t-ratio
Constant       135.44          27.18        4.98
C5         0.00000737     0.00001773        0.42

s = 168.1       R-sq = 0.4%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE       DF          SS           MS
Regression    1        4881         4881
Error        44     1243660        28265
Total        45     1248540

Unusual Observations
Obs.      C5        C10        Fit Stdev.Fit  Residual    St.Resid
  4  9670000      144.9      206.7     162.3     -61.8      -1.40 X
 40   773000      875.4      141.1      24.9     734.3       4.42R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c10 1 c6

The regression equation is
C10 = 122 +0.000005 C6

Predictor        Coef          Stdev     t-ratio
Constant       121.75          38.89        3.13
C6         0.00000532     0.00000872        0.61

s = 167.7       R-sq = 0.8%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE       DF          SS           MS
Regression    1       10482        10482
Error        44     1238058        28138
Total        45     1248540
```

```
Unusual Observations
Obs.       C6         C10        Fit  Stdev.Fit   Residual    St.Resid
  4  10100000       144.9      175.5       63.1      -30.6     -0.20 X
  5  13236000         0.0      192.2       88.9     -192.2     -1.35 X
 40   5549000       875.4      151.3       30.8      724.1      4.39R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > hist c5

Histogram of C5   N = 46

 Midpoint    Count
        0       30  ******************************
  1000000       15  ***************
  2000000        0
  3000000        0
  4000000        0
  5000000        0
  6000000        0
  7000000        0
  8000000        0
  9000000        0
 10000000        1  *

MTB > hist c6

Histogram of C6   N = 46

 Midpoint    Count
        0       11  ***********
  2000000       13  *************
  4000000       11  ***********
  6000000        6  ******
  8000000        3  ***
 10000000        1  *
 12000000        0
 14000000        1  *

MTB > let c11 =1/c5
MTB > hist c11

Histogram of C11   N = 46

Midpoint    Count
 0.00000       29  *****************************
 0.00001       11  ***********
 0.00002        5  *****
 0.00003        0
 0.00004        0
 0.00005        0
 0.00006        0
 0.00007        1  *
```

```
MTB > let c12 = logt(c5)
MTB > hist c12

Histogram of C12   N = 46

Midpoint   Count
     4.0       1  *
     4.4       0
     4.8      11  ***********
     5.2       6  ******
     5.6      17  *****************
     6.0      10  **********
     6.4       0
     6.8       1  *

MTB > let c13 = sqrt(c5)
MTB > hist c13

Histogram of C13   N = 46

Midpoint   Count
       0       1  *
     400      21  *********************
     800      17  *****************
    1200       6  ******
    1600       0
    2000       0
    2400       0
    2800       0
    3200       1  *

MTB > let c14 = logt(c6)
MTB > hist c14

Histogram of C14   N = 46

Midpoint   Count
     4.6       1  *
     4.8       0
     5.0       0
     5.2       0
     5.4       0
     5.6       1  *
     5.8       7  *******
     6.0       3  ***
     6.2       7  *******
     6.4       5  *****
     6.6      11  ***********
     6.8       8  ********
     7.0       2  **
     7.2       1  *


MTB > let c15 =sqrt(c6)
MTB > hist c15

Histogram of C15   N = 46

Midpoint   Count
       0       1  *
     500       3  ***
    1000      10  **********
    1500      10  **********
    2000      11  ***********
    2500       6  ******
    3000       4  ****
    3500       1  *
```

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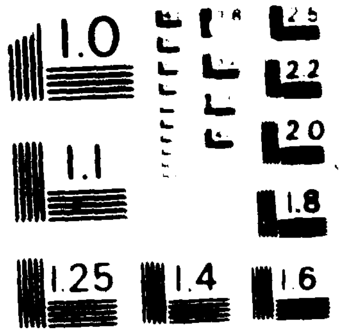

1.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

```
MTB > regr c4 1 c12

The regression equation is
C4 = - 162157 + 38306 C12

Predictor        Coef          Stdev     t-ratio
Constant      -162157         183401       -0.88
C12             38306          33473        1.14

s = 119122       R-sq = 2.9%      R-sq(adj) = 0.7%

Analysis of Variance

SOURCE          DF            SS           MS
Regression       1   18583924736  18583924736
Error           44  624358588416  14189965312
Total           45  642942500864

Unusual Observations
Obs.      C12          C4          Fit Stdev.Fit   Residual    St.Resid
  4      6.99       21000       105427     54188     -84427     -0.80 X
  6      4.15       25500        -3335     47168      28835      0.26 X
 40      5.89      766336        63396     22798     702940      6.01R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c10 1 c12

The regression equation is
C10 = - 272 + 75.6 C12

Predictor        Coef          Stdev     t-ratio
Constant       -272.0          251.7       -1.08
C12             75.56          45.94        1.64

s = 163.5        R-sq = 5.8%      R-sq(adj) = 3.7%

Analysis of Variance

SOURCE          DF            SS           MS
Regression       1         72308        72308
Error           44       1176233        26733
Total           45       1248541


Unusual Observations
Obs.      C12         C10          Fit Stdev.Fit   Residual    St.Resid
  4      6.99       144.9        255.8      74.4     -110.9     -0.76 X
  6      4.15       159.7         41.3      64.7      118.4      0.79 X
 38      4.97       452.4        103.4      32.8      349.0      2.18R
 40      5.89       875.4        172.9      31.3      702.5      4.38R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c4  1 c15

The regression equation is
C4 = 10166 + 21.6 C15

Predictor        Coef          Stdev     t-ratio
Constant        10166          43442        0.23
C15             21.59          23.42        0.92

s = 119730       R-sq = 1.9%      R-sq(adj) = 0.0%
```

Analysis of Variance

SOURCE	DF	SS	MS
Regression	1	12185374720	12185374720
Error	44	630757130240	14335385600
Total	45	642942500864	

Unusual Observations

Obs.	C15	C4	Fit	Stdev.Fit	Residual	St.Resid
5	3638	0	88709	48802	-88709	-0.81 X
40	2356	766336	61021	23470	705315	6.01R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c10 1 c15

The regression equation is
C10 = 80.3 + 0.0353 C15

Predictor	Coef	Stdev	t-ratio
Constant	80.28	60.32	1.33
C15	0.03527	0.03251	1.08

s = 166.2 R-sq = 2.6% R-sq(adj) = 0.4%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	1	32526	32526
Error	44	1216014	27637
Total	45	1248540	

Unusual Observations

Obs.	C15	C10	Fit	Stdev.Fit	Residual	St.Resid
5	3638	0.0	208.6	67.8	-208.6	-1.37 X
38	844	452.4	110.0	37.0	342.4	2.11R
40	2356	875.4	163.4	32.6	712.0	4.37R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c10 2 c12 c15

The regression equation is
C10 = - 286 + 79.2 C12 - 0.0036 C15

Predictor	Coef	Stdev	t-ratio
Constant	-285.7	308.7	-0.93
C12	79.17	65.50	1.21
C15	-0.00356	0.04559	-0.08

s = 165.4 R-sq = 5.8% R-sq(adj) = 1.4%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	2	72475	36237
Error	43	1176066	27350
Total	45	1248540	

SOURCE	DF	SEQ SS
C12	1	72308
C15	1	167

Unusual Observations

Obs.	C12	C10	Fit	Stdev.Fit	Residual	St.Resid
4	6.99	144.9	256.0	75.3	-111.1	-0.75 X
6	4.15	159.7	37.0	84.9	122.7	0.86 X
38	4.97	452.4	104.7	37.0	347.8	2.16R
40	5.89	875.4	172.1	33.2	703.3	4.34R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

```
MTB > plot c4 c5

       -
       -
 750000+     *  #40
       -
C4     -
       -
       -
 500000+
       -
       -
       -
       -
 250000+
       - * *
       -        *
       -   3*
       - * 3* *
      0+ +65422**                                        *  #4
         +---------+---------+---------+---------+---------+------C5
         0   2000000   4000000   6000000   8000000  10000000
MTB > plot c4 c6

       -
       -
 750000+                       *  #40
       -
C4     -
       -
       -
 500000+
       -
       -
       -
       -
 250000+
       -    * #38   *
       -            *
       -        *        *      *   *
       -        *  *   ***              *
      0+ * 343*2*3     ***2** **   *    *   *    *            *
         +---------+---------+---------+---------+---------+------C6
         0   2500000   5000000   7500000  10000000  12500000

MTB > delete 40 c1-c6
MTB > delete 38 c1-c6
MTB > delete 4 c1-c6
```

```
MTB > print c1-c6
 ROW     C1     C2       C3        C4         C5          C6

MTB > print c1-c6
 ROW     C1     C2       C3        C4         C5          C6

   1      1   1166     1308      4380    1166000     1308000
   2      2    403     3470         0     403000     3470000
   3      3   1030     1745      5389    1030000     1745000
   4      5   1050    13236         0    1050000    13236000
   5      6     14     2426     25500      14000     2426000
   6      7    391     5454     12191     391000     5454000
   7      8    578     7690     67519     578000     7690000
   8      9    636     8833         0     636000     8833000
   9     10    147     1945         0     147000     1945000
  10     11    352     1774    115896     352000     1774000
  11     12    374     2835    188610     374000     2835000
  12     13    561     5158         0     561000     5158000
  13     14     48      398         0      48000      398000
  14     15    723     4300     13498     723000     4300000
  15     16   1354     7644      3720    1354000     7644000
  16     17     65      957         0      65000      957000
  17     18    368     3575     74675     368000     3575000
  18     19    361     3925      8528     361000     3925000
  19     20    427     2107     11180     427000     2107000
  20     21    763     4613     15611     763000     4613000
  21     22    313     5788     88962     313000     5788000
  22     23    352     3699     41016     352000     3699000
  23     24    447     4075    101121     447000     4075000
  24     25    580     6692     93000     580000     6692000
  25     26    104     6556         0     104000     6556000
  26     27     70     1008         0      70000     1008000
  27     28     73      977      2911      73000      977000
  28     29   1082     3905     45669    1082000     3905000
  29     30    312     1669     27676     312000     1669000
  30     31    111      651      4450     111000      651000
  31     32    494     4666       623     494000     4666000
  32     33     77      791      6551      77000      791000
  33     34   1494     2634    146034    1494000     2634000
  34     35     61      511      3048      61000      511000
  35     36    626     4203      5488     626000     4203000
  36     37    157     1591      7373     157000     1591000
  37     39    213     2066      1370     213000     2066000
  38     41    187     1394      5961     187000     1394000
  39     42     68       41         0      68000       41000
  40     43     80      701      1520      80000      701000
  41     44    525     3773      9608     525000     3773000
  42     45     65      658      1431      65000      658000
  43     46     52      522     18503      52000      522000

MTB > let c20 = sqrt(c4)
MTB > hist c4

Histogram of C4   N = 43

Midpoint    Count
       0       26  **************************
   20000        7  *******
   40000        2  **
   60000        1  *
   80000        2  **
  100000        2  **
  120000        1  *
  140000        1  *
  160000        0
  180000        1  *
```

```
MTB > hist c20

Histogram of C20   N = 43

Midpoint   Count
       0      11  ***********
      50      10  **********
     100       9  *********
     150       3  ***
     200       2  **
     250       2  **
     300       3  ***
     350       1  *
     400       1  *
     450       1  *

MTB > regr c4 1 c5

The regression equation is
C4 = 15351 + 0.0272 C5

Predictor        Coef          Stdev     t-ratio
Constant        15351          10079        1.52
C5            0.02718        0.01772        1.53

s = 43670       R-sq = 5.4%      R-sq(adj) = 3.1%

Analysis of Variance

SOURCE        DF            SS            MS
Regression     1    4486594560    4486594560
Error         41   78189297664    1907055872
Total         42   82675892224


Unusual Observations
Obs.      C5          C4         Fit Stdev.Fit   Residual    St.Resid
 10   352000      115896       24919      6790      90977       2.11R
 11   374000      188610       25517      6725     163092       3.78R
 15  1354000        3720       52158     17730     -48438      -1.21 X
 33  1494000      146034       55963     20051      90071       2.32RX

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.
```

```
MTB > regr c20 1 c5

The regression equation is
C20 = 82.7 +0.000077 C5

Predictor        Coef         Stdev     t-ratio
Constant        82.74         26.69        3.10
C5         0.00007697    0.00004694        1.64

s = 115.7       R-sq = 6.2%      R-sq(adj) = 3.9%

Analysis of Variance

SOURCE        DF          SS          MS
Regression     1       35966       35966
Error         41      548496       13378
Total         42      584461

Unusual Observations
Obs.       C5        C20        Fit Stdev.Fit   Residual    St.Resid
 10    352000      340.4      109.8      18.0      230.6       2.02R
 11    374000      434.3      111.5      17.8      322.8       2.82R
 15   1354000       61.0      187.0      47.0     -126.0      -1.19 X
 33   1494000      382.1      197.7      53.1      184.4       1.79 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c4 1 c6

The regression equation is
C4 = 21906 + 0.00153 C6

Predictor        Coef         Stdev     t-ratio
Constant        21906         10774        2.03
C6           0.001529      0.002527        0.61

s = 44706       R-sq = 0.9%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF          SS          MS
Regression     1   731589632   731589632
Error         41 81944313856  1998641664
Total         42 82675892224

Unusual Observations
Obs.       C6         C4        Fit Stdev.Fit   Residual    St.Resid
  4  13236000          0      42143     26014     -42143      -1.16 X
 10   1774000     115896      24618      7835      91278       2.07R
 11   2835000     188610      26241      6919     162369       3.68R
 33   2634000     146034      25933      7023     120101       2.72R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c20 1 c6

The regression equation is
C20 = 104 +0.000003 C6

Predictor        Coef         Stdev     t-ratio
Constant       104.07         28.68        3.63
C6         0.00000349    0.00000673        0.52

s = 119.0       R-sq = 0.7%      R-sq(adj) = 0.0%
```

```
Analysis of Variance

SOURCE         DF          SS          MS
Regression      1        3816        3816
Error          41      580646       14162
Total          42      584461

Unusual Observations
Obs.       C6         C20       Fit  Stdev.Fit   Residual    St.Resid
  4  13236000         0.0     150.3       69.2     -150.3     -1.55 X
 11   2835000       434.3     114.0       18.4      320.3      2.72R
 33   2634000       382.1     113.3       18.7      268.9      2.29R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > let c21 = sqrt(c5)
MTB > hist c5

Histogram of C5   N = 43

Midpoint   Count
       0      11  ***********
  200000       6  ******
  400000      12  ************
  600000       6  ******
  800000       2  **
 1000000       3  ***
 1200000       1  *
 1400000       2  **

MTB > hist c21

Histogram of C21   N = 43

Midpoint   Count
     100       1  *
     200       3  ***
     300       9  *********
     400       3  ***
     500       1  *
     600       9  *********
     700       5  *****
     800       4  ****
     900       2  **
    1000       3  ***
    1100       1  *
    1200       2  **

MTB > let c22 = logt(c5)
MTB > hist c22

Histogram of C22   N = 43

Midpoint   Count
     4.2       1  *
     4.4       0
     4.6       1  *
     4.8       8  ********
     5.0       3  ***
     5.2       3  ***
     5.4       3  ***
     5.6      10  **********
     5.8       8  ********
     6.0       4  ****
     6.2       2  **
```

```
MTB > let c23 = sqrt(c6)
MTB > hist c23

Histogram of C23   N = 43

Midpoint   Count
       0       1  *
     500       3  ***
    1000       9  *********
    1500      10  **********
    2000      11  ***********
    2500       5  *****
    3000       3  ***
    3500       1  *

MTB > regr c4 1 c21

The regression equation is
C4 = 2792 + 41.1 C21

Predictor        Coef          Stdev     t-ratio
Constant         2792          15101        0.18
C21             41.11          23.11        1.78

s = 43267       R-sq = 7.2%      R-sq(adj) = 4.9%

Analysis of Variance

SOURCE        DF           SS            MS
Regression     1   5923262464    5923262464
Error         41  76752617472    1872014848
Total         42  82675826688

Unusual Observations
Obs.      C21         C4         Fit Stdev.Fit   Residual    St.Resid
 10       593     115896       27185      6599      88711       2.07R
 11       612     188610       27936      6621     160674       3.76R
 33      1222     146034       53046     16084      92988       2.32R

R denotes an obs. with a large st. resid.

MTB > regr c20 1 c21

The regression equation is
C20 = 45.5 + 0.119 C21

Predictor        Coef          Stdev     t-ratio
Constant        45.53          39.86        1.14
C21           0.11922        0.06100        1.95

s = 114.2       R-sq = 8.5%      R-sq(adj) = 6.3%

Analysis of Variance

SOURCE        DF           SS            MS
Regression     1        49805         49805
Error         41       534656         13040
Total         42       584461


Unusual Observations
Obs.      C21        C20         Fit Stdev.Fit   Residual    St.Resid
 11       612      434.3       118.4      17.5      315.9       2.80R

R denotes an obs. with a large st. resid.
```

```
MTB > regr c4 1 c23

The regression equation is
C4 = 9661 + 10.4 C23

Predictor        Coef          Stdev     t-ratio
Constant         9661          16853        0.57
C23            10.385          9.275        1.12

s = 44234        R-sq = 3.0%      R-sq(adj) = 0.6%

Analysis of Variance

SOURCE        DF           SS           MS
Regression     1   2453259264   2453259264
Error         41  80222683136   1956650752
Total         42  82675892224

Unusual Observations
Obs.      C23          C4        Fit  Stdev.Fit   Residual    St.Resid
  4      3638           0      47445      19504     -47445     -1.20 X
 10      1332      115896      23494       7420      92402      2.12R
 11      1684      188610      27148       6748     161462      3.69R
 33      1623      146034      26516       6757     119518      2.73R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c20 1 c23

The regression equation is
C20 = 67.0 + 0.0292 C23

Predictor        Coef          Stdev     t-ratio
Constant        67.01          44.73        1.50
C23           0.02917        0.02462        1.19

s = 117.4        R-sq = 3.3%      R-sq(adj) = 1.0%

Analysis of Variance

SOURCE        DF           SS           MS
Regression     1        19360        19360
Error         41       565101        13783
Total         42       584461


Unusual Observations
Obs.      C23         C20        Fit  Stdev.Fit   Residual    St.Resid
  4      3638         0.0      173.2       51.8     -173.2     -1.64 X
 10      1332       340.4      105.9       19.7      234.6      2.03R
 11      1684       434.3      116.1       17.9      318.2      2.74R
 33      1623       382.1      114.4       17.9      267.8      2.31R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c20 2 c21 c23

The regression equation is
C20 = 45.9 + 0.120 C21 - 0.0005 C23

Predictor        Coef          Stdev     t-ratio
Constant        45.87          46.22        0.99
C21           0.11997        0.07949        1.51
C23          -0.00047        0.03120       -0.01

s = 115.6        R-sq = 8.5%      R-sq(adj) = 3.9%
```

Analysis of Variance

SOURCE	DF	SS	MS
Regression	2	49808	24904
Error	40	534654	13366
Total	42	584461	

SOURCE	DF	SEQ SS
C21	1	49805
C23	1	3

Unusual Observations

Obs.	C21	C20	Fit	Stdev.Fit	Residual	St.Resid
1	1080	66.2	174.9	53.9	-108.7	-1.06 X
11	612	434.3	118.5	17.7	315.8	2.76R
33	1222	382.1	191.7	54.2	190.4	1.86 X

R denot s an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > plot c4 c5

```
        -
        -            * #11
 180000+
        -
C4      -
        -                                                     *
        -
 120000+             *
        -
        -               *   *
        -          *
        -            *      *
  60000+
        -                                   *
        -            *
        - * *      *
        -   * *      ***   *     **
     0+   72****      *  *  * 2          **   *     *
        +---------+---------+---------+---------+---------+------C5
        0    300000    600000    900000   1200000   1500000
```

MTB > plot c4 c6

```
        -
        -         * #11
 180000+
        -
C4      -
        -         * #33
        -
 120000+      *
        -
        -              *          *
        -                     *
        -             *                   *
  60000+
        -              *
        -             *
        -  *    *  *
        -   *  * *    ****   *
     0+ * 233***2     *  * * *   *    *   *                  * #4
        +---------+---------+---------+---------+---------+------C6
        0   2500000   5000000   7500000  10000000  12500000
```

```
MTB > delete 33 c1-c6
MTB > delete 11 c1-c6
MTB > delete 4 c1-c6
MTB > print c1-c6
```

ROW	C1	C2	C3	C4	C5	C6
1	1	1166	1308	4380	1166000	1308000
2	2	403	3470	0	403000	3470000
3	3	1030	1745	5389	1030000	1745000
4	6	14	2426	25500	14000	2426000
5	7	391	5454	12191	391000	5454000
6	8	578	7690	67519	578000	7690000
7	9	636	8833	0	636000	8833000
8	10	147	1945	0	147000	1945000
9	11	352	1774	115896	352000	1774000
10	13	561	5158	0	561000	5158000
11	14	48	398	0	48000	398000
12	15	723	4300	13498	723000	4300000
13	16	1354	7644	3720	1354000	7644000
14	17	65	957	0	65000	957000
15	18	368	3575	74675	368000	3575000
16	19	361	3925	8528	361000	3925000
17	20	427	2107	11180	427000	2107000
18	21	763	4613	15611	763000	4613000
19	22	313	5788	88962	313000	5788000
20	23	352	3699	41016	352000	3699000
21	24	447	4075	101121	447000	4075000
22	25	580	6692	93000	580000	6692000
23	26	104	6556	0	104000	6556000
24	27	70	1008	0	70000	1008000
25	28	73	977	2911	73000	977000
26	29	1082	3905	45669	1082000	3905000
27	30	312	1669	27676	312000	1669000
28	31	111	651	4450	111000	651000
29	32	494	4666	623	494000	4666000
30	33	77	791	6551	77000	791000
31	35	61	511	3048	61000	511000
32	36	626	4203	5488	626000	4203000
33	37	157	1591	7373	157000	1591000
34	39	213	2066	1370	213000	2066000
35	41	187	1394	5961	187000	1394000
36	42	68	41	0	68000	41000
37	43	80	701	1520	80000	701000
38	44	525	3773	9608	525000	3773000
39	45	65	658	1431	65000	658000
40	46	52	522	18503	52000	522000

```
MTB > let c30 = sqrt(c4)
MTB > hist c4

Histogram of C4   N = 40

Midpoint   Count
       0      18  ******************
   10000      10  **********
   20000       2  **
   30000       2  **
   40000       1  *
   50000       1  *
   60000       0
   70000       2  **
   80000       0
   90000       2  **
  100000       1  *
  110000       0
  120000       1  *
```

```
MTB > hist c30

Histogram of C30   N = 40

Midpoint   Count
       0      10  **********
      50      10  **********
     100       9  *********
     150       3  ***
     200       2  **
     250       2  **
     300       3  ***
     350       1  *

MTB > regr c4 1 c5

The regression equation is
C4 = 16045 + 0.0118 C5

Predictor        Coef          Stdev     t-ratio
Constant        16045           7774        2.06
C5            0.01183        0.01522        0.78

s = 32200        R-sq = 1.6%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF           SS           MS
Regression     1    625817344    625817344
Error         38  39400640512   1036858880
Total         39  40026456064


Unusual Observations
Obs.     C5          C4        Fit  Stdev.Fit   Residual    St.Resid
  1  1166000       4380      29835      12921     -25455     -0.86 X
  9   352000     115896      20208       5117      95688      3.01R
 13  1354000       3720      32058      15592     -28338     -1.01 X
 19   313000      88962      19747       5211      69215      2.18R
 21   447000     101121      21332       5176      79789      2.51R
 22   580000      93000      22905       5887      70095      2.21R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c30 1 c5

The regression equation is
C30 = 82.1 +0.000056 C5

Predictor        Coef          Stdev     t-ratio
Constant        82.08          24.10        3.41
C5         0.00005643     0.00004719        1.20

s = 99.83        R-sq = 3.6%      R-sq(adj) = 1.1%

Analysis of Variance

SOURCE        DF           SS           MS
Regression     1        14247        14247
Error         38       378719         9966
Total         39       392966
```

```
Unusual Observations
Obs.       C5        C30        Fit  Stdev.Fit   Residual    St.Resid
  1   1166000       66.2      147.9       40.1      -81.7      -0.89 X
  9    352000      340.4      101.9       15.9      238.5       2.42R
 13   1354000       61.0      158.5       48.3      -97.5      -1.12 X
 19    313000      298.3       99.7       16.2      198.5       2.02R
 21    447000      318.0      107.3       16.0      210.7       2.14R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.


MTB > regr c4 1 c6

The regression equation is
C4 = 8304 + 0.00399 C6

Predictor        Coef         Stdev     t-ratio
Constant         8304          8208        1.01
C6           0.003993      0.002135        1.87

s = 31056       R-sq = 8.4%      R-sq(adj) = 6.0%

Analysis of Variance

SOURCE       DF           SS           MS
Regression    1   3375790592   3375790592
Error        38  36650668032    964491264
Total        39  40026456064

Unusual Observations
Obs.       C6         C4        Fit  Stdev.Fit   Residual    St.Resid
  7   8833000          0      43577      13222     -43577      -1.55 X
  9   1774000     115896      15388       5648     100508       3.29R
 21   4075000     101121      24577       5349      76544       2.50R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c30 1 c6

The regression equation is
C30 = 68.0 +0.000012 C6

Predictor        Coef         Stdev     t-ratio
Constant        67.98         25.88        2.63
C6         0.00001164    0.00000673        1.73

s = 97.91       R-sq = 7.3%      R-sq(adj) = 4.9%

Analysis of Variance

SOURCE       DF           SS           MS
Regression    1        28690        28690
Error        38       364276         9586
Total        39       392966


Unusual Observations
Obs.       C6        C30        Fit  Stdev.Fit   Residual    St.Resid
  7   8833000        0.0      170.8       41.7     -170.8      -1.93 X
  9   1774000      340.4       88.6       17.8      251.8       2.62R
 21   4075000      318.0      115.4       16.9      202.6       2.10R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.
```

```
MTB > let c31 = sqrt(c5)
MTB > hist c5

Histogram of C5   N = 40

Midpoint   Count
       0      11  ***********
  200000       6  ******
  400000      11  ***********
  600000       6  ******
  800000       2  **
 1000000       2  **
 1200000       1  *
 1400000       1  *

MTB > hist c31

Histogram of C31   N = 40

Midpoint   Count
     100       1  *
     200       3  ***
     300       9  *********
     400       3  ***
     500       1  *
     600       8  ********
     700       5  <****
     800       4  ****
     900       2  **
    1000       2  **
    1100       1  *
    1200       1  *

MTB > let c32 = sqrt(c6)
MTB > hist c6

Histogram of C6   N = 40

 Midpoint   Count
        0       2  **
  1000000      11  ***********
  2000000       8  ********
  3000000       1  *
  4000000       8  ********
  5000000       4  ****
  6000000       1  *
  7000000       2  **
  8000000       2  **
  9000000       1  *

MTB > hist c32

Histogram of C32   N = 40

Midpoint   Count
     400       1  *
     800       9  *********
    1200       8  ********
    1600       3  ***
    2000      11  ***********
    2400       5  *****
    2800       3  ***
```

```
MTB > let c33 = logt(c6)
MTB > hist c33

Histogram of C33   N = 40

Midpoint   Count
     4.6       1  *
     4.8       0
     5.0       0
     5.2       0
     5.4       0
     5.6       1  *
     5.8       6  ******
     6.0       3  ***
     6.2       7  *******
     6.4       3  ***
     6.6      11  ***********
     6.8       7  *******
     7.0       1  *

MTB > regr c4 1 c31

The regression equation is
C4 = 7095 + 24.1 C31

Predictor        Coef          Stdev      t-ratio
Constant         7095          11629         0.61
C31             24.12          18.72         1.29

s = 31768       R-sq = 4.2%       R-sq(adj) = 1.7%

Analysis of Variance

SOURCE        DF           SS           MS
Regression     1   1675502336   1675502336
Error         38  38350954496   1009235456
Total         39  40026456064


Unusual Observations
Obs.      C31          C4          Fit  Stdev.Fit   Residual    St.Resid
  9       593      115896        21406       5061      94490       3.01R
 13      1164        3720        35162      12361     -31442      -1.07 X
 19       559       88962        20590       5023      68372       2.18R
 21       669      101121        23222       5417      77899       2.49R
 22       762       93000        25465       6280      67535       2.17R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c30 1 c31

The regression equation is
C30 = 49.6 + 0.0968 C31

Predictor        Coef          Stdev      t-ratio
Constant        49.64          35.93         1.38
C31           0.09676        0.05783         1.67

s = 98.14       R-sq = 6.9%       R-sq(adj) = 4.4%

Analysis of Variance

SOURCE        DF           SS           MS
Regression     1        26960        26960
Error         38       366006         9632
Total         39       392966
```

Unusual Observations

Obs.	C31	C30	Fit	Stdev.Fit	Residual	St.Resid
9	593	340.4	107.0	15.6	233.4	2.41R
13	1164	61.0	162.2	38.2	-101.2	-1.12 X
19	559	298.3	103.8	15.5	194.5	2.01R
21	669	318.0	114.3	16.7	203.7	2.11R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c30 2 c31 c6

The regression equation is
C30 = 48.2 + 0.0575 C31 +0.000008 C6

Predictor	Coef	Stdev	t-ratio
Constant	48.21	36.05	1.34
C31	0.05750	0.07263	0.79
C6	0.00000760	0.00000847	0.90

s = 98.39   R-sq = 8.8%   R-sq(adj) = 3.9%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	2	34758	17379
Error	37	358208	9681
Total	39	392966	

SOURCE	DF	SEQ SS
C31	1	26960
C6	1	7798

Unusual Observations

Obs.	C31	C30	Fit	Stdev.Fit	Residual	St.Resid
1	1080	66.2	120.2	50.7	-54.1	-0.64 X
9	593	340.4	95.8	20.1	244.6	2.54R
21	669	318.0	117.6	17.2	200.4	2.07R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > plot c4 c5

```
        -               *
        -
  105000+
        -                   *
C4      -              *         *
        -
        -                *
   70000+                        *
        -
        -
        -                                            *
        -               *
   35000+
        -  *          *
        -   *
        -                 **           * *
        -    ** **      *      *   *               *     *      *
       0+   26* *  *      *   * *  *
          +---------+---------+---------+---------+---------+------C5
          0    250000    500000    750000   1000000   1250000
```

```
MTB > plot c4 c6
         -            *
         -
   105000+
         -                          *
C4       -                                     *     *
         -
         -                       *
    70000+                                                 *
         -
         -
         -                         *
         -                        *
    35000+
         -           *    *
         -    *
         -              *             * *    *
         -     **  ****            ***                     *
        0+ * **2 3     **        *      *  *        *             *
           +---------+---------+---------+---------+---------+------C6
           0   1600000   3200000   4800000   6400000   8000000
```

APPENDIX E

REGRESSION ON VERY COMPLEX PROJECTS

```
 C1  NUMERICAL LISTING OF THE PROJECTS
 C2  THE A/E COSTS IN THOUSANDS
 C3  THE CONSTRUCTION COSTS IN THOUSANDS
 C4  A/E LIABILITY COSTS
 C5  THE A/E COSTS
 C6  THE CONSTRUCTION COSTS

MTB > let c5 = 1000*c2
MTB > let c6 = 1000*c3
MTB > print c1-c6
 ROW    C1     C2      C3       C4        C5         C6

   1     1   8512   15411    10154   8512000   15411000
   2     2    589    6928        0    589000    6928000
   3     3   1347    9912  1616460   1347000    9912000
   4     4    766    7947   132298    766000    7947000
   5     5   1349   20566     4950   1349000   20566000
   6     6  10156    4896    24064  10156000    4896000
   7     7    731    5150    88581    731000    5150000
   8     8   1116   14083    55536   1116000   14083000
   9     9    985    1143    48526    985000    1143000
  10    10   2117    6091   199719   2117000    6091000
  11    11   3433    5399    17520   3433000    5399000

MTB > regr c4 1 c5

The regression equation is
C4 = 274527 - 0.0264 C5

Predictor       Coef          Stdev     t-ratio
Constant      274527         198002        1.39
C5          -0.02643        0.04653       -0.57

s = 490781      R-sq = 3.5%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE      DF           SS           MS
Regression   1  77711671296  77711671296
Error        9 2.167797E+12 240866295808
Total       10 2.245508E+12


Unusual Observations
Obs.      C5        C4        Fit Stdev.Fit  Residual    St.Resid
  3  1347000   1616460     238926    163223   1377533       2.98R
  6 10156000     24064       6106    371728     17958       0.06 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c4 1 c6

The regression equation is
C4 = 184115 + 0.0018 C6

Predictor       Coef          Stdev     t-ratio
Constant      184115         289193        0.64
C6           0.00177        0.02785        0.06

s = 499389      R-sq = 0.0%      R-sq(adj) = 0.0%
```

```
Analysis of Variance

SOURCE          DF            SS             MS
Regression       1    1006483712     1006483712
Error            9  2.244502E+12   249389121536
Total           10  2.245508E+12

Unusual Observations
Obs.        C6          C4         Fit  Stdev.Fit   Residual     St.Resid
  3    9912000     1616460      201651     153363    1414808        2.98R

R denotes an obs. with a large st. resid.

MTB > hist c4

Histogram of C4   N = 11

Midpoint    Count
       0        8  ********
  200000        2  **
  400000        0
  600000        0
  800000        0
 1000000        0
 1200000        0
 1400000        0
 1600000        1  *


MTB > let c10 = sqrt(c4)
MTB > hist c10

Histogram of C10   N = 11

Midpoint    Count
       0        2  **
     200        6  ******
     400        2  **
     600        0
     800        0
    1000        0
    1200        1  *

MTB > regr c10 1 c5

The regression equation is
C10 = 368 -0.000024 C5

Predictor         Coef          Stdev      t-ratio
Constant         368.0          144.0         2.56
C5         -0.00002424     0.00003383        -0.72

s = 356.8         R-sq = 5.4%       R-sq(adj) = 0.0%

Analysis of Variance

SOURCE          DF           SS           MS
Regression       1        65364        65364
Error            9      1145913       127324
Total           10      1211277

Unusual Observations
Obs.        C5          C10        Fit  Stdev.Fit   Residual     St.Resid
  3    1347000         1271        335        119        936        2.78R
  6   10156000          155        122        270         33        0.14 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.
```

```
MTB > regr c10 1 c6

The regression equation is
C10 = 338 -0.000004 C6

Predictor        Coef           Stdev      t-ratio
Constant        338.5           211.9         1.60
C6        -0.00000440      0.00002041        -0.22

s = 365.9        R-sq = 0.5%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE          DF          SS           MS
Regression       1        6221         6221
Error            9     1205056       133895
Total           10     1211277


Unusual Observations
Obs.        C6        C10        Fit  Stdev.Fit   Residual     St.Resid
  3   9912000       1271        295        112        977        2.80R

R denotes an obs. with a large st. resid.

MTB > hist c5

Histogram of C5   N = 11

 Midpoint    Count
  1000000        7  *******
  2000000        1  *
  3000000        1  *
  4000000        0
  5000000        0
  6000000        0
  7000000        0
  8000000        0
  9000000        1  *
 10000000        1  *

MTB > hist c6

Histogram of C6   N = 11

 Midpoint    Count
  2000000        1  *
  4000000        1  *
  6000000        4  ****
  8000000        1  *
 10000000        1  *
 12000000        0
 14000000        1  *
 16000000        1  *
 18000000        0
 20000000        1  *
```

```
MTB > let c11 = sqrt(c5)
MTB > hist c11

Histogram of C11   N = 11

Midpoint   Count
     800       4  ****
    1200       3  ***
    1600       1  *
    2000       1  *
    2400       0
    2800       1  *
    3200       1  *


MTB > let c12 = logt(c5)
MTB > hist c12

Histogram of C12   N = 11

Midpoint   Count
     5.8       3  ***
     6.0       2  **
     6.2       2  **
     6.4       1  *
     6.6       1  *
     6.8       0
     7.0       2  **

MTB > let c13 = 1/c5
MTB > hist c13

Histogram of C13   N = 11

 Midpoint   Count
0.0000000       1  *
0.0000002       2  **
0.0000004       1  *
0.0000006       0
0.0000008       3  ***
0.0000010       1  *
0.0000012       0
0.0000014       2  **
0.0000016       1  *

MTB > let c14 = sqrt(c6)
MTB > hist c14

Histogram of C14   N = 11

Midpoint   Count
    1000       1  *
    1500       0
    2000       1  *
    2500       4  ****
    3000       2  **
    3500       0
    4000       2  **
    4500       1  *
```

```
MTB > let c15 = logt(c6)
MTB > hist c15

Histogram of C15   N = 11

Midpoint   Count
     6.0       1  *
     6.2       0
     6.4       0
     6.6       1  *
     6.8       4  ****
     7.0       2  **
     7.2       2  **
     7.4       1  *

MTB > regr c4 1 c11

The regression equation is
C4 = 335756 - 92 C11

Predictor        Coef          Stdev      t-ratio
Constant       335756         313153         1.07
C11             -91.9          186.2        -0.49

s = 492884       R-sq = 2.6%       R-sq(adj) = 0.0%

Analysis of Variance

SOURCE         DF           SS             MS
Regression      1  59099402240    59099402240
Error           9 2.186409E+12 242934284288
Total          10 2.245508E+12

Unusual Observations
Obs.      C11         C4        Fit Stdev.Fit   Residual    St.Resid
  3      1161    1616460     229146    160078    1387313       2.98R

R denotes an obs. with a large st. resid.

MTB > regr c10 1 c11

The regression equation is
C10 = 425 - 0.085 C11

Predictor        Coef          Stdev      t-ratio
Constant        425.0          228.2         1.86
C11           -0.0848         0.1357        -0.63

s = 359.1        R-sq = 4.2%       R-sq(adj) = 0.0%

Analysis of Variance

SOURCE         DF           SS             MS
Regression      1        50400          50400
Error           9      1160876         128986
Total          10      1211276

Unusual Observations
Obs.      C11        C10        Fit Stdev.Fit   Residual    St.Resid
  3      1161       1271        327       117        945       2.78R

R denotes an obs. with a large st. resid.
```

```
MTB > regr c4 1 c15

The regression equation is
C4 = - 967939 + 170443 C15

Predictor        Coef          Stdev     t-ratio
Constant      -967939        3196534       -0.30
C15            170443         466054        0.37

s = 495830      R-sq = 1.5%       R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF            SS           MS
Regression     1   32881381376  32881381376
Error          9 2.212627E+12 245847490560
Total         10 2.245509E+12

Unusual Observations
Obs.     C15        C4        Fit Stdev.Fit  Residual    St.Resid
  3     7.00   1616460     224506    164052   1391954       2.97R
  9     6.06     48526      64611    398745    -16085      -0.05 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c10 1 c15

The regression equation is
C10 = - 15 + 46 C15

Predictor        Coef          Stdev     t-ratio
Constant          -15           2363       -0.01
C15              45.9          344.5        0.13

s = 366.5       R-sq = 0.2%       R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF            SS           MS
Regression     1          2381         2381
Error          9       1208896       134322
Total         10       1211277


Unusual Observations
Obs.     C15       C10        Fit Stdev.Fit  Residual    St.Resid
  3     7.00      1271        306       121       965       2.79R
  9     6.06       220        263       295       -43      -0.20 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c10 2 c5 c6

The regression equation is
C10 = 401 -0.000024 C5 -0.000004 C6

Predictor        Coef          Stdev     t-ratio
Constant        400.6          237.7        1.69
C5        -0.00002395     0.00003585       -0.67
C6        -0.00000377     0.00002108       -0.18

s = 377.7       R-sq = 5.8%       R-sq(adj) = 0.0%
```

```
Analysis of Variance

SOURCE         DF          SS          MS
Regression      2       69921       34960
Error           8     1141356      142669
Total          10     1211277

SOURCE         DF      SEQ SS
C5              1       65364
C6              1        4557

Unusual Observations
Obs.       C5         C10        Fit  Stdev.Fit   Residual    St.Resid
  3   1347000        1271        331        128        940       2.65R

R denotes an obs. with a large st. resid.

MTB > plot c4 c5

         -
         -        *  #3
  1500000+
         -
C4       -
         -
         -
  1000000+
         -
         -
         -
         -
   500000+
         -
         -
         -
         -            *
         -     2 *
        0+    * * *         *                         *       *
           +---------+---------+---------+---------+---------+------C5
           0   2000000   4000000   6000000   8000000  10000000

MTB > plot c4 c6

         -
         -                          *  #3
  1500000+
         -
C4       -
         -
         -
  1000000+
         -
         -
         -
         -
   500000+
         -
         -
         -
         -                *
         -              *      *              *
        0+    *        **   *                     *           *
           +---------+---------+---------+---------+---------+------C6
           0   4000000   8000000  12000000  16000000  20000000
```

```
MTB > delete 3 c1- c6
MTB > print c1-c6
 ROW     C1        C2        C3         C4          C5           C6

   1      1      8512     15411      10154     8512000     15411000
   2      2       589      6928          0      589000      6928000
   3      4       766      7947     132298      766000      7947000
   4      5      1349     20566       4950     1349000     20566000
   5      6     10156      4896      24064    10156000      4896000
   6      7       731      5150      88581      731000      5150000
   7      8      1116     14083      55536     1116000     14083000
   8      9       985      1143      48526      985000      1143000
   9     10      2117      6091     199719     2117000      6091000
  10     11      3433      5399      17520     3433000      5399000

MTB > let c20 = sqrt(c4)
MTB > hist c4

Histogram of C4   N = 10

Midpoint    Count
       0        2  **
   20000        3  ***
   40000        1  *
   60000        1  *
   80000        1  *
  100000        0
  120000        0
  140000        1  *
  160000        0
  180000        0
  200000        1  *

MTB > hist c20

Histogram of C20    N = 10

Midpoint    Count
       0        1  *
      50        1  *
     100        1  *
     150        2  **
     200        1  *
     250        1  *
     300        1  *
     350        1  *
     400        0
     450        1  *

MTB > regr c4 1 c5

The regression equation is
C4 = 75451 - 0.00582 C5

Predictor        Coef          Stdev     t-ratio
Constant        75451          27846        2.71
C5          -0.005820       0.006268       -0.93

s = 65390       R-sq = 9.7%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE         DF            SS            MS
Regression      1    3686365184    3686365184
Error           8   34206769152    4275846144
Total           9   37893132288
```

Unusual Observations

Obs.	C5	C4	Fit	Stdev.Fit	Residual	St.Resid
9	2117000	199719	63130	21367	136588	2.21R

R denotes an obs. with a large st. resid.

```
MTB > regr c20 1 c5
```

The regression equation is
C20 = 233 -0.000010 C5

Predictor	Coef	Stdev	t-ratio
Constant	232.73	60.37	3.86
C5	-0.00001023	0.00001359	-0.75

s = 141.8   R-sq = 6.6%   R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	1	11401	11401
Error	8	160770	20096
Total	9	172171	

```
MTB > regr c4 1 c6
```

The regression equation is
C4 = 87153 - 0.00331 C6

Predictor	Coef	Stdev	t-ratio
Constant	87153	38202	2.28
C6	-0.003312	0.003662	-0.90

s = 65554   R-sq = 9.3%   R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	1	3514463488	3514463488
Error	8	34378670080	4297330688
Total	9	37893132288	

Unusual Observations

Obs.	C6	C4	Fit	Stdev.Fit	Residual	St.Resid
9	6091000	199719	66979	22921	132740	2.16R

R denotes an obs. with a large st. resid.

```
MTB > regr c20 1 c6
```

The regression equation is
C20 = 272 -0.000008 C6

Predictor	Coef	Stdev	t-ratio
Constant	271.54	80.37	3.38
C6	-0.00000791	0.00000770	-1.03

s = 137.9   R-sq = 11.6%   R-sq(adj) = 0.6%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	1	20022	20022
Error	8	152149	19019
Total	9	172171	

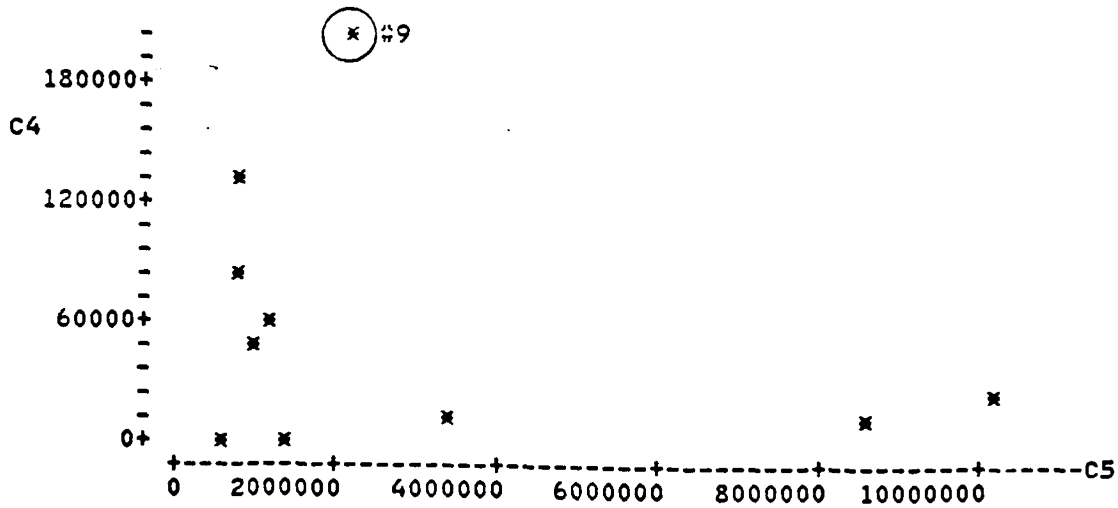
```
MTB > hist c5

Histogram of C5   N = 10

 Midpoint   Count
  1000000       6  ******
  2000000       1  *
  3000000       1  *
  4000000       0
  5000000       0
  6000000       0
  7000000       0
  8000000       0
  9000000       1  *
 10000000       1  *

MTB > hist c6

Histogram of C6   N = 10

 Midpoint   Count
  2000000       1  *
  4000000       1  *
  6000000       4  ****
  8000000       1  *
 10000000       0
 12000000       0
 14000000       1  *
 16000000       1  *
 18000000       0
 20000000       1  *

MTB > let c21 = sqrt(c5)
MTB > hist c21

Histogram of C21   N = 10

Midpoint   Count
     800       4  ****
    1200       2  **
    1600       1  *
    2000       1  *
    2400       0
    2800       1  *
    3200       1  *


MTB > let c22 = logt(c5)
MTB > hist c22

Histogram of C22   N = 10

Midpoint   Count
     5.8       3  ***
     6.0       2  **
     6.2       1  *
     6.4       1  *
     6.6       1  *
     6.8       0
     7.0       2  **
```

```
MTB > let c23 =1/c5
MTB > hist c23

Histogram of C23   N = 10

 Midpoint   Count
0.0000000       1  *
0.0000002       2  **
0.0000004       1  *
0.0000006       0
0.0000008       2  **
0.0000010       1  *
0.0000012       0
0.0000014       2  **
0.0000016       1  *

MTB > let c24 =sqrt(c6)
MTB > hist c24

Histogram of C24   N = 10

Midpoint   Count
    1000       1  *
    1500       0
    2000       1  *
    2500       4  ****
    3000       1  *
    3500       0
    4000       2  **
    4500       1  *

MTB > let c25 = logt(c6)
MTB > hist c25

Histogram of C25   N = 10

Midpoint   Count
     6.0       1  *
     6.2       0
     6.4       0
     6.6       1  *
     6.8       4  ****
     7.0       1  *
     7.2       2  **
     7.4       1  *


MTB > regr c4 1 c21

The regression equation is
C4 = 90066 - 21.1 C21

Predictor       Coef         Stdev     t-ratio
Constant       90066         43348        2.08
C21           -21.12         25.13       -0.84

s = 65973       R-sq = 8.1%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE       DF            SS           MS
Regression    1    3073592064   3073592064
Error         8   34819543040   4352442368
Total         9   37893132288

Unusual Observations
Obs.     C21         C4        Fit  Stdev.Fit   Residual    St.Resid
  9     1455     199719      59339      20912     140380       2.24R

R denotes an obs. with a large st. resid.
```

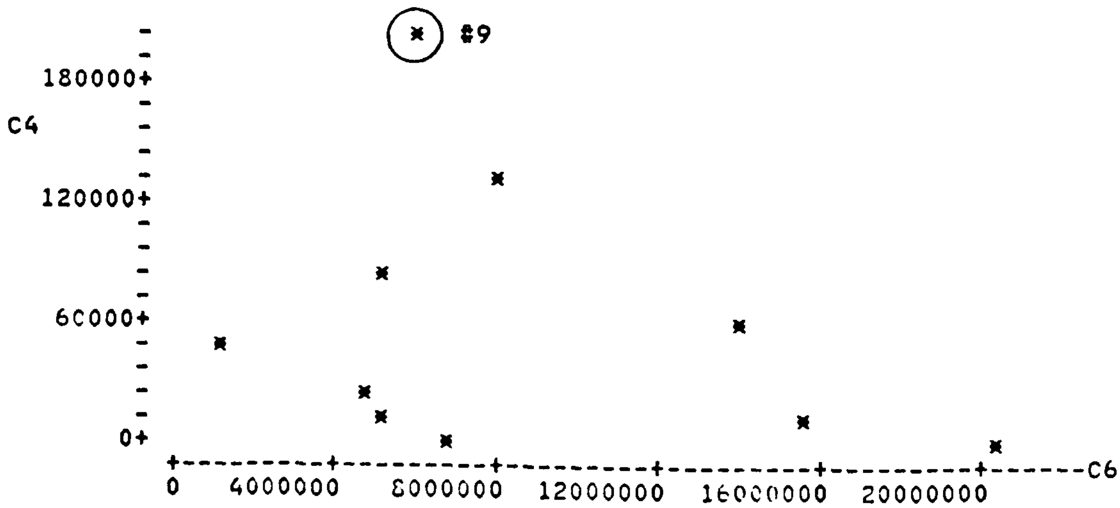
```
MTB > regr c20 1 c21

The regression equation is
C20 = 258 - 0.0367 C21

Predictor       Coef          Stdev     t-ratio
Constant      257.70          93.76        2.75
C21         -0.03665        0.05436       -0.67

s = 142.7       R-sq = 5.4%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE       DF         SS         MS
Regression    1       9258       9258
Error         8     162913      20364
Total         9     172171


MTB > regr c4 1 c25

The regression equation is
C4 = 261352 - 29724 C25

Predictor       Coef          Stdev     t-ratio
Constant      261352         441563        0.59
C25           -29724          64511       -0.46

s = 67928       R-sq = 2.6%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE       DF           SS           MS
Regression    1    979619328    979619328
Error         8  36913516544   4614189056
Total         9  37893132288

Unusual Observations
Obs.      C25         C4        Fit  Stdev.Fit   Residual    St.Resid
  8      6.06      48526      81280      54633     -32754     -0.81 X
  9      6.78     199719      59681      21741     140038      2.18R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c20 1 c25

The regression equation is
C20 = 838 - 93 C25

Predictor       Coef          Stdev     t-ratio
Constant       837.7          926.7        0.90
C25            -92.9          135.4       -0.69

s = 142.6       R-sq = 5.6%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE       DF         SS         MS
Regression    1       9578       9578
Error         8     162593      20324
Total         9     172171
```

```
Obs.     C25      C20        Fit  Stdev.Fit  Residual   St.Resid
  3      6.06     220.3      274.7    114.7     -54.4     -0.64 X

X denotes an obs. whose X value gives it large influence.

MTB > regr c20 2 c5 c6

The regression equation is
C20 = 297 -0.000010 C5 -0.000008 C6

Predictor        Coef          Stdev      t-ratio
Constant       297.24          90.92        3.27
C5        -0.00000952     0.00001369       -0.70
C6        -0.00000760     0.00000798       -0.95

s = 142.6       R-sq = 17.3%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF         SS          MS
Regression     2      29867       14933
Error          7     142304       20329
Total          9     172171

SOURCE        DF     SEQ SS
C5             1      11401
C6             1      18466
```

MTB > plot c4 c5



MTB > plot c4 c6



```
MTB > delete 9 c1-c6
MTB > print c1-c6
 ROW     C1       C2       C3        C4          C5          C6

   1      1     8512    15411     10154     8512000    15411000
   2      2      589     6928         0      589000     6928000
   3      4      766     7947    132298      766000     7947000
   4      5     1349    20566      4950     1349000    20566000
   5      6    10156     4896     24064    10156000     4896000
   6      7      731     5150     88581      731000     5150000
   7      8     1116    14083     55536     1116000    14083000
   8      9      985     1143     48526      985000     1143000
   9     11     3433     5399     17520     3433000     5399000

MTB > let c30 = sqrt(c4)
MTB > hist c4

Histogram of C4   N = 9

Midpoint    Count
       0        2  **
   20000        3  ***
   40000        1  *
   60000        1  *
   80000        1  *
  100000        0
  120000        0
  140000        1  *

MTB > hist c30

Histogram of C30   N = 9

Midpoint    Count
       0        1  *
      50        1  *
     100        1  *
     150        2  **
     200        1  *
     250        1  *
     300        1  *
     350        1  *

MTB > regr c4 1 c5

The regression equation is
C4 = 56571 - 0.00461 C5

Predictor       Coef          Stdev      t-ratio
Constant       56571          19431         2.91
C5         -0.004614       0.004197        -1.10

s = 43622        R-sq = 14.7%      R-sq(adj) = 2.5%

Analysis of Variance

SOURCE        DF            SS           MS
Regression     1    2299405056   2299405056
Error          7   13320302592   1902900224
Total          8   15619706880
```

```
MTB > regr c30 1 c5

The regression equation is
C30 = 200 -0.000008 C5

Predictor        Coef          Stdev     t-ratio
Constant       200.14          52.84        3.79
C5        -0.00000815     0.00001141       -0.71

s = 118.6       R-sq = 6.8%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF          SS          MS
Regression     1        7179        7179
Error          7       98505       14072
Total          8      105684


MTB > regr c4 1 c6

The regression equation is
C4 = 60986 - 0.00205 C6

Predictor        Coef          Stdev     t-ratio
Constant        60986          27635        2.21
C6          -0.002052       0.002557       -0.80

s = 45205       R-sq = 8.4%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF           SS            MS
Regression     1   1315051520    1315051520
Error          7  14304653312    2043521792
Total          8  15619702784

Unusual Observations
Obs.      C6         C4        Fit  Stdev.Fit   Residual    St.Resid
  3  7947000     132298      44683      15334      87615       2.06R

R denotes an obs. with a large st. resid.

MTB > regr c30 1 c6

The regression equation is
C30 = 227 -0.000006 C6

Predictor        Coef          Stdev     t-ratio
Constant       227.48          71.30        3.19
C6        -0.00000578     0.00000660       -0.88

s = 116.6       R-sq = 9.9%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF          SS          MS
Regression     1       10449       10449
Error          7       95235       13605
Total          8      105684
```

```
MTB > hist c5

Histogram of C5   N = 9

 Midpoint   Count
  1000000       6  ******
  2000000       0
  3000000       1  *
  4000000       0
  5000000       0
  6000000       0
  7000000       0
  8000000       0
  9000000       1  *
 10000000       1  *

MTB > hist c6

Histogram of C6   N = 9

 Midpoint   Count
  2000000       1  *
  4000000       1  *
  6000000       3  ***
  8000000       1  *
 10000000       0
 12000000       0
 14000000       1  *
 16000000       1  *
 18000000       0
 20000000       1  *

MTB > let c31 = sqrt(c5)
MTB > hist c31

Histogram of C31   N = 9

Midpoint   Count
     800       4  ****
    1200       2  **
    1600       0
    2000       1  *
    2400       0
    2800       1  *
    3200       1  *


MTB > let c32 = logt(c5)
MTB > hist c32

Histogram of C32   N = 9

Midpoint   Count
     5.8       3  ***
     6.0       2  **
     6.2       1  *
     6.4       0
     6.6       1  *
     6.8       0
     7.0       2  **
```

```
MTB > let c33 = 1/c5
MTB > hist c33

Histogram of C33   N = 9

 Midpoint   Count
0.0000000       1  *
0.0000002       2  **
0.0000004       0
0.0000006       0
0.0000008       2  **
0.0000010       1  *
0.0000012       0
0.0000014       2  **
0.0000016       1  *

MTB > let c34 = sqrt(c6)
MTB > hist c34

Histogram of C34   N = 9

Midpoint   Count
    1000       1  *
    1500       0
    2000       1  *
    2500       3  ***
    3000       1  *
    3500       0
    4000       2  **
    4500       1  *

MTB > regr c4 1 c31

The regression equation is
C4 = 72507 - 19.8 C31

Predictor        Coef          Stdev     t-ratio
Constant        72507          28676        2.53
C31            -19.83          16.36       -1.21

s = 42948        R-sq = 17.3%      R-sq(adj) = 5.5%

Analysis of Variance

SOURCE        DF           SS            MS
Regression     1   2707759616    2707759616
Error          7  12911947776    1844563968
Total          8  15619706880


MTB > regr c30 1 c31

The regression equation is
C30 = 227 - 0.0344 C31

Predictor        Coef          Stdev     t-ratio
Constant       227.36          78.81        2.89
C31          -0.03442        0.04497       -0.77

s = 118.0        R-sq = 7.7%       R-sq(adj) = 0.0%
```

```
Analysis of Variance

SOURCE        DF          SS          MS
Regression     1        8161        8161
Error          7       97524       13932
Total          8      105684


MTB > regr c4 1 c34

The regression equation is
C4 = 71380 - 10.2 C34

Predictor       Coef          Stdev      t-ratio
Constant       71380          45808         1.56
C34           -10.21          15.22        -0.67

s = 45788       R-sq = 6.0%       R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF          SS          MS
Regression     1   943696128   943696128
Error          7 14676008960  2096572672
Total          8 15619702784

Unusual Observations
Obs.     C34         C4        Fit Stdev.Fit   Residual    St.Resid
  3     2819     132298      42594     15265      89704       2.08R

R denotes an obs. with a large st. resid.

MTB > regr c30 1 c34

The regression equation is
C30 = 265 - 0.0316 C34

Predictor       Coef          Stdev      t-ratio
Constant       264.7          117.6         2.25
C34         -0.03159        0.03906        -0.81

s = 117.5       R-sq = 8.5%       R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF          SS          MS
Regression     1        9029        9029
Error          7       96656       13808
Total          8      105684


MTB > regr c4 2 c31 c34

The regression equation is
C4 = 95595 - 18.9 C31 - 8.6 C34

Predictor       Coef          Stdev      t-ratio
Constant       95595          50336         1.90
C31           -18.88          17.29        -1.09
C34            -8.64          15.08        -0.57

s = 45171       R-sq = 21.6%      R-sq(adj) = 0.0%
```

Analysis of Variance

SOURCE	DF	SS	MS
Regression	2	3377426688	1688713216
Error	6	12242280448	2040379904
Total	8	15619706880	

SOURCE	DF	SEQ SS
C31	1	2707759616
C34	1	669666816

```
MTB > plot c4 c5

          -     *
          -
    120000+
          -
C4        -
          -
          -     *
     80000+
          -
          -
          -       *
          -      *
     40000+
          -
          -                                                    *
          -                  *
          -        *                                   *
         0+    *
            +---------+---------+---------+---------+---------+------C5
            0   2000000   4000000   6000000   8000000  10000000
MTB > plot c4 c6

          -                     *
          -
    120000+
          -
C4        -
          -
          -              *
     80000+
          -
          -
          -                                    *
          -    *
     40000+
          -
          -             *
          -              *
          -                                        *           *
         0+                  *
            +---------+---------+---------+---------+---------+------C6
            0   4000000   8000000  12000000  16000000  20000000
```

APPENDIX F

REGRESSION ON ALL PROJECTS

C1 NUMERICAL LISTING OF THE PROJECTS
C2 THE A/E COSTS IN THOUSANDS
C3 THE CONSTRUCTION COSTS IN THOUSANDS
C4 A/E LIABILITY COSTS
C5 THE A/E COSTS
C6 THE CONSTRUCTION COSTS

```
MTB > let c5 =1000*c2
MTB > let c6 = 1000*c3
MTB > print c1-c6
```

ROW	C1	C2	C3	C4	C5	C6
1	1	95	48	0	95000	48000
2	2	116	584	3520	116000	584000
3	3	250	6210	0	250000	6210000
4	4	166	3180	0	166000	3180000
5	5	13	3524	100000	13000	3524000
6	6	412	6882	100000	412000	6882000
7	7	26	320	30800	26000	320000
8	8	364	31789	0	364000	31788992
9	9	234	3664	162001	234000	3664000
10	10	551	7726	89608	551000	7726000
11	11	190	2066	4693	190000	2066000
12	12	488	5451	40826	488000	5451000
13	13	177	1386	17240	177000	1386000
14	14	1869	7984	12568	1869000	7984000
15	15	261	2496	0	261000	2496000
16	16	4	120	3079	4000	120000
17	17	415	4604	9331	415000	4604000
18	18	421	2860	20327	421000	2860000
19	19	861	12264	74980	861000	12264000
20	20	417	3607	1007	417000	3607000
21	21	150	1908	25684	150000	1908000
22	22	26	153	1615	26000	153000
23	23	4	967	73154	4000	967000
24	24	289	4935	5453	289000	4935000
25	25	1141	8001	123555	1141000	8001000
26	26	421	1737	5159	421000	1737000
27	27	198	847	2757	198000	847000
28	28	84	619	2441	84000	619000
29	29	409	4567	8913	409000	4567000
30	30	107	854	19714	107000	854000
31	31	159	87	0	159000	87000
32	32	472	1295	63558	472000	1295000
33	33	108	133	2160	108000	133000
34	34	192	161	7200	192000	161000
35	1	1166	1308	4380	1166000	1308000
36	2	403	3470	0	403000	3470000
37	3	1030	1745	5389	1030000	1745000
38	4	9670	10100	21000	9670000	10100000
39	5	1050	13236	0	1050000	13236000
40	6	14	2426	25500	14000	2426000
41	7	391	5454	12191	391000	5454000
42	8	578	7690	67519	578000	7690000
43	9	636	8833	0	636000	8833000
44	10	147	1945	0	147000	1945000
45	11	352	1774	115896	352000	1774000
46	12	374	2835	188610	374000	2835000
47	13	561	5158	0	561000	5158000
48	14	48	398	0	48000	398000
49	15	723	4300	13498	723000	4300000

50	16	1354	7644	3720	1354000	7644000
51	17	65	957	0	65000	957000
52	18	368	3575	74675	368000	3575000
53	19	361	3925	8528	361000	3925000
54	20	427	2107	11180	427000	2107000
55	21	763	4613	15611	763000	4613000
56	22	313	5788	88962	313000	5788000
57	23	352	3699	41016	352000	3699000
58	24	447	4075	101121	447000	40[illegible]5000
59	25	580	6692	93000	580000	6692000
60	26	104	6556	0	104000	6556000
61	27	70	1008	0	70000	1008000
62	28	73	977	2911	73000	977000
63	29	1082	3905	45669	1082000	3905000
64	30	312	1669	27676	312000	1669000
65	31	111	651	4450	111000	651000
66	32	494	4666	623	494000	4666000
67	33	77	791	6551	77000	791000
68	34	1494	2634	146034	1494000	2634000
69	35	61	511	3048	61000	511000
70	36	626	4203	5488	626000	4203000
71	37	157	1591	7373	157000	1591000
72	38	93	712	204700	93000	712000
73	39	213	2066	1370	213000	2066000
74	40	773	5549	766336	773000	5549000
75	41	187	1394	5961	187000	1394000
76	42	68	41	0	68000	41000
77	43	80	701	1520	80000	701000
78	44	525	3773	9608	525000	3773000
79	45	65	658	1431	65000	658000
80	46	52	522	18503	52000	522000
81	1	8512	15411	10154	8512000	15411000
82	2	589	6928	0	589000	6928000
83	3	1347	9912	1616460	1347000	9912000
84	4	766	7947	132298	766000	7947000
85	5	1349	20566	4950	1349000	20566000
86	6	10156	4896	24064	10156000	4896000
87	7	731	5150	88581	731000	5150000
88	8	1116	14083	55536	1116000	14083000
89	9	985	1143	48526	985000	1143000
90	10	2117	6091	199719	2117000	6091000
91	11	3433	5399	17520	3433000	5399000

```
MTB > let c10 = sqrt(c4)
MTB > hist c4

Histogram of C4   N = 91
Each * represents 2 obs.

Midpoint    Count
       0       78  ***************************************
  200000       11  ******
  400000        0
  600000        0
  800000        1  *
 1000000        0
 1200000        0
 1400000        0
 1600000        1  *
```

```
MTB > hist c10

Histogram of C10   N = 91

Midpoint   Count
       0      25  *************************
     100      34  **********************************
     200      10  **********
     300      13  *************
     400       6  ******
     500       1  *
     600       0
     700       0
     800       0
     900       1  *
    1000       0
    1100       0
    1200       0
    1300       1  *

MTB > regr c4 1 c5

The regression equation is
C4 = 55884 + 0.0039 C5

Predictor        Coef          Stdev     t-ratio
Constant        55884          21892        2.55
C5            0.00387        0.01176        0.33

s = 189558      R-sq = 0.1%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF            SS            MS
Regression     1    3880218880    3880218880
Error         89  3.197973E+12   35932282880
Total         90  3.201853E+12

Unusual Observations
Obs.      C5         C4        Fit  Stdev.Fit   Residual    St.Resid
 38   9670000      21000     93262     106430     -72262      -0.46 X
 74    773000     766336     58872      19871     707464       3.75R
 81   8512000      10154     88786      93083     -78632      -0.48 X
 83   1347000    1616460     61091      20956    1555369       8.26R
 86  10156000      24064     95141     112051     -71077      -0.46 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c10 1 c5

The regression equation is
C10 = 149 +0.000008 C5

Predictor        Coef          Stdev     t-ratio
Constant       148.75          21.75        6.84
C5         0.00000805     0.00001169        0.69

s = 188.3       R-sq = 0.5%      R-sq(adj) = 0.0%

Analysis of Variance

SOURCE        DF            SS            MS
Regression     1         16845         16845
Error         89       3155833         35459
Total         90       3172678
```

```
Unusual Observations
Obs.       C5        C10        Fit  Stdev.Fit   Residual    St.Resid
 38   9670000      144.9      226.6      105.7      -81.7     -0.52 X
 74    773000      875.4      155.0       19.7      720.4      3.85R
 81   8512000      100.8      217.3       92.5     -116.5     -0.71 X
 83   1347000     1271.4      159.6       20.8     1111.8      5.94R
 86  10156000      155.1      230.5      111.3      -75.4     -0.50 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c4 1 c6

The regression equation is
C4 = 35833 + 0.00540 C6

Predictor        Coef          Stdev     t-ratio
Constant        35833          26501        1.35
C6           0.005399       0.004149        1.30

s = 187894       R-sq = 1.9%      R-sq(adj) = 0.8%

Analysis of Variance

SOURCE        DF          SS            MS
Regression     1   59777138688   59777138688
Error         89  3.142077E+12   35304230912
Total         90  3.201853E+12

Unusual Observations
Obs.       C6         C4        Fit  Stdev.Fit   Residual    St.Resid
  8  31788992          0     207449     115845    -207449     -1.40 X
 74   5549000     766336      65790      20395     700546      3.75R
 81  15411000      10154     119031      50231    -108877     -0.60 X
 83   9912000    1616460      89344      30581    1527116      8.24R
 85  20566000       4950     146861      70407    -141911     -0.81 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c10 1 c6

The regression equation is
C10 = 134 +0.000005 C6

Predictor        Coef          Stdev     t-ratio
Constant       133.56          26.41        5.06
C6         0.00000503     0.00000413        1.22

s = 187.3        R-sq = 1.6%      R-sq(adj) = 0.5%

Analysis of Variance

SOURCE        DF          SS            MS
Regression     1       51855         51855
Error         89     3120823         35065
Total         90     3172678

Unusual Observations
Obs.       C6        C10        Fit  Stdev.Fit   Residual    St.Resid
  8  31788992        0.0      293.4      115.5     -293.4     -1.99 X
 74   5549000      875.4      161.5       20.3      713.9      3.84R
 81  15411000      100.8      211.0       50.1     -110.3     -0.61 X
 83   9912000     1271.4      183.4       30.5     1088.0      5.89R
 85  20566000       70.4      237.0       70.2     -166.6     -0.96 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.
```

```
MTB > hist c5

Histogram of C5   N = 91
Each * represents 2 obs.

 Midpoint   Count
        0      60  ******************************
  1000000      25  *************
  2000000       2  *
  3000000       1  *
  4000000       0
  5000000       0
  6000000       0
  7000000       0
  8000000       0
  9000000       1  *
 10000000       2  *

MTB > hist c6

Histogram of C6   N = 91

 Midpoint   Count
        0      36  ************************************
  4000000      34  **********************************
  8000000      14  **************
 12000000       3  ***
 16000000       2  **
 20000000       1  *
 24000000       0
 28000000       0
 32000000       1  *


MTB > let c11 = sqrt(c5)
MTB > let c12 = logt(c5)
MTB > let c13= 1/c5
MTB > hist c11

Histogram of C11   N = 91

Midpoint   Count
       0       6  ******
     400      37  *************************************
     800      32  ********************************
    1200      11  ***********
    1600       1  *
    2000       1  *
    2400       0
    2800       1  *
    3200       2  **

MTB > hist c12

Histogram of C12   N = 91

Midpoint   Count
     3.6       2  **
     4.0       2  **
     4.4       2  **
     4.8      13  *************
     5.2      18  ******************
     5.6      30  ******************************
     6.0      18  ******************
     6.4       3  ***
     6.8       2  **
     7.2       1  *
```

```
MTB > hist c13

Histogram of C13   N = 91
Each * represents 2 obs.

Midpoint   Count
 0.00000      72  ************************************
 0.00002      13  *******
 0.00004       2  *
 0.00006       0
 0.00008       2  *
 0.00010       0
 0.00012       0
 0.00014       0
 0.00016       0
 0.00018       0
 0.00020       0
 0.00022       0
 0.00024       0
 0.00026       2  *


MTB > let c14 = sqrt(c6)
MTB > let c15 =logt(c6)
MTB > let c16= 1/c6
MTB > hist c14

Histogram of C14   N = 91

Midpoint   Count
       0       2  **
     500       9  *********
    1000      18  ******************
    1500      15  ***************
    2000      19  *******************
    2500      13  *************
    3000       9  *********
    3500       2  **
    4000       2  **
    4500       1  *
    5000       0
    5500       1  *

MTB > hist c15

Histogram of C15   N = 91

Midpoint   Count
     4.8       3  ***
     5.2       4  ****
     5.6       6  ******
     6.0      16  ****************
     6.4      25  *************************
     6.8      30  ******************************
     7.2       6  ******
     7.6       1  *
```

```
MTB > hist c16

Histogram of C16   N = 91
Each * represents 2 obs.

Midpoint   Count
0.000000     68  **********************************
0.000002     15  ********
0.000004      1  *
0.000006      2  *
0.000008      2  *
0.000010      0
0.000012      1  *
0.000014      0
0.000016      0
0.000018      0
0.000020      1  *
0.000022      0
0.000024      1  *

MTB > regr c4 1 c12

The regression equation is
C4 = - 213919 + 49887 C12

Predictor        Coef          Stdev     t-ratio
Constant      -213919         174134       -1.23
C12             49887          31638        1.58

s = 187078       R-sq = 2.7%       R-sq(adj) = 1.6%

Analysis of Variance

SOURCE        DF           SS            MS
Regression     1  87012343808   87012343808
Error         89 3.114841E+12   34998214656
Total         90 3.201853E+12

Unusual Observations
Obs.     C12         C4        Fit  Stdev.Fit   Residual    St.Resid
 16     3.60       3079     -34225      62233      37304      0.21 X
 23     3.60      73154     -34225      62233     107379      0.61 X
 38     6.99      21000     134559      51835    -113559     -0.63 X
 74     5.89     766336      79822      23677     686514      3.70R
 81     6.93      10154     131796      50217    -121642     -0.67 X
 83     6.13    1616460      91854      28658    1524606      8.25R
 86     7.01      24064     135622      52459    -111558     -0.62 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c10 1 c12

The regression equation is
C10 = - 211 + 66.9 C12

Predictor        Coef          Stdev     t-ratio
Constant       -211.0          171.3       -1.23
C12             66.94          31.13        2.15

s = 184.1        R-sq = 4.9%       R-sq(adj) = 3.9%

Analysis of Variance

SOURCE        DF           SS            MS
Regression     1       156660        156660
Error         89      3016018         33888
Total         90      3172677
```

```
Unusual Observations
Obs.      C12        C10        Fit  Stdev.Fit   Residual    St.Resid
 16      3.60       55.5       30.1       61.2       25.4       0.15 X
 23      3.60      270.5       30.1       61.2      240.4       1.38 X
 38      6.99      144.9      256.6       51.0     -111.6      -0.63 X
 74      5.89      875.4      183.1       23.3      692.3       3.79R
 81      6.93      100.8      252.9       49.4     -152.1      -0.86 X
 83      6.13     1271.4      199.3       28.2     1072.1       5.89R
 86      7.01      155.1      258.0       51.6     -102.9      -0.58 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c4 1 c14

The regression equation is
C4 = - 4763 + 35.2 C14

Predictor        Coef           Stdev     t-ratio
Constant        -4763           40523       -0.12
C14             35.15           19.60        1.79

s = 186337      R-sq = 3.5%      R-sq(adj) = 2.4%

Analysis of Variance

SOURCE        DF            SS            MS
Regression     1 111652241408 111652241408
Error         89 3.090202E+12  34721366016
Total         90 3.201853E+12

Unusual Observations
Obs.      C14         C4        Fit  Stdev.Fit   Residual    St.Resid
  8      5638          0     193428      77519    -193428      -1.14 X
 74      2356     766336      78041      22259     688295       3.72R
 83      3148    1616460     105906      32689    1510554       8.23R
 85      4535       4950     154648      56854    -149698      -0.84 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c10 1 c14

The regression equation is
C10 = 79.0 + 0.0420 C14

Predictor        Coef           Stdev     t-ratio
Constant        79.01           40.02        1.97
C14           0.04198         0.01936        2.17

s = 184.0       R-sq = 5.0%      R-sq(adj) = 4.0%

Analysis of Variance

SOURCE        DF            SS            MS
Regression     1        159240        159240
Error         89       3013438         33859
Total         90       3172677

Unusual Observations
Obs.      C14        C10        Fit  Stdev.Fit   Residual    St.Resid
  8      5638        0.0      315.7       76.6     -315.7      -1.89 X
 74      2356      875.4      177.9       22.0      697.5       3.82R
 83      3148     1271.4      211.2       32.3     1060.2       5.85R
 85      4535       70.4      269.4       56.1     -199.0      -1.14 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.
```

MTB > regr c10 2 c12 c14

The regression equation is
C10 = - 112 + 40.3 C12 + 0.0260 C14

Predictor	Coef	Stdev	t-ratio
Constant	-112.5	196.0	-0.57
C12	40.30	40.38	1.00
C14	0.02601	0.02512	1.04

s = 184.0   R-sq = 6.1%   R-sq(adj) = 3.9%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	2	192972	96486
Error	88	2979706	33860
Total	90	3172677	

SOURCE	DF	SEQ SS
C12	1	156660
C14	1	36312

Unusual Observations

Obs.	C12	C10	Fit	Stdev.Fit	Residual	St.Resid
5	4.11	316.2	102.2	59.0	214.1	1.23 X
8	5.56	0.0	258.3	95.7	-258.3	-1.64 X
16	3.60	55.5	41.7	62.2	13.8	0.08 X
23	3.60	270.5	58.3	67.0	212.2	1.24 X
74	5.89	875.4	186.1	23.5	689.3	3.78R
83	6.13	1271.4	216.4	32.7	1055.0	5.83R
85	6.13	70.4	252.5	58.6	-182.2	-1.04 X
86	7.01	155.1	227.5	59.4	-72.3	-0.42 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > plot c4 c5

```
          -
          -         *  #83
   1500000+
          -
C4        -
          -
          -
   1000000+
          -
          -      *  #74
          -
          -
    500000+
          -
          -
          - ***       *
          - 2 633 2*                                        #81  #38 #86
        0+ +++524*2 *       *                                 *    *  *
           +---------+---------+---------+---------+---------+---------C5
           0    2000000   4000000   6000000   8000000  10000000
```

```
MTB > plot c4 c6

        -
        -                   *  #83
 1500000+
        -
C4      -
        -
        -
 1000000+
        -
        -           *  #74
        -
        -
  500000+
        -
        -
        -  *    **   *
        -   2** 2* **2  4      *  *
       0+ 7+78324464***2  * *    *   *       *                  *
          +---------+---------+---------+---------+---------+------C6
          0   6000000  12000000  18000000  24000000  30000000
MTB > delete 86 c1-c6
MTB > delete 83 c1-c6
MTB > delete 81 c1-c6
MTB > delete 74 c1-c6
MTB > delete 38 c1-c6
MTB > print c1-c6
```

ROW	C1	C2	C3	C4	C5	C6
1	1	95	48	0	95000	48000
2	2	116	584	3520	116000	584000
3	3	250	6210	0	250000	6210000
4	4	166	3180	0	166000	3180000
5	5	13	3524	100000	13000	3524000
6	6	412	6882	100000	412000	6882000
7	7	26	320	30800	26000	320000
8	8	364	31789	0	364000	31788992
9	9	234	3664	162001	234000	3664000
10	10	551	7726	89608	551000	7726000
11	11	190	2066	4693	190000	2066000
12	12	488	5451	40826	488000	5451000
13	13	177	1386	17240	177000	1386000
14	14	1869	7984	12568	1869000	7984000
15	15	261	2496	0	261000	2496000
16	16	4	120	3079	4000	120000
17	17	415	4604	9331	415000	4604000
18	18	421	2860	20327	421000	2860000
19	19	861	12264	74980	861000	12264000
20	20	417	3607	1007	417000	3607000
21	21	150	1908	25684	150000	1908000
22	22	26	153	1615	26000	153000
23	23	4	967	73154	4000	967000
24	24	289	4935	5453	289000	4935000
25	25	1141	8001	123555	1141000	8001000
26	26	421	1737	5159	421000	1737000
27	27	198	847	2757	198000	847000
28	28	84	619	2441	84000	619000
29	29	409	4567	8913	409000	4567000
30	30	107	854	19714	107000	854000
31	31	159	87	0	159000	87000
32	32	472	1295	63558	472000	1295000
33	33	108	133	2160	108000	133000
34	34	192	161	7200	192000	161000
35	1	1166	1308	4380	1166000	1308000
36	2	403	3470	0	403000	3470000
37	3	1030	1745	5389	1030000	1745000

38	5	1050	13236	0	1050000	13236000
39	6	14	2426	25500	14000	2426000
40	7	391	5454	12191	391000	5454000
41	8	578	7690	67519	578000	7690000
42	9	636	8833	0	636000	8833000
43	10	147	1945	0	147000	1945000
44	11	352	1774	115896	352000	1774000
45	12	374	2835	188610	374000	2835000
46	13	561	5158	0	561000	5158000
47	14	48	398	0	48000	398000
48	15	723	4300	13498	723000	4300000
49	16	1354	7644	3720	1354000	7644000
50	17	65	957	0	65000	957000
51	18	368	3575	74675	368000	3575000
52	19	361	3925	8528	361000	3925000
53	20	427	2107	11180	427000	2107000
54	21	763	4613	15611	763000	4613000
55	22	313	5788	88962	313000	5788000
56	23	352	3699	41016	352000	3699000
57	24	447	4075	101121	447000	4075000
58	25	580	6692	93000	580000	6692000
59	26	104	6556	0	104000	6556000
60	27	70	1008	0	70000	1008000
61	28	73	977	2911	73000	977000
62	29	1082	3905	45669	1082000	3905000
63	30	312	1669	27676	312000	1669000
64	31	111	651	4450	111000	651000
65	32	494	4666	623	494000	4666000
66	33	77	791	6551	77000	791000
67	34	1494	2634	146034	1494000	2634000
68	35	61	511	3048	61000	511000
69	36	626	4203	5488	626000	4203000
70	37	157	1591	7373	157000	1591000
71	38	93	712	204700	93000	712000
72	39	213	2066	1370	213000	2066000
73	41	187	1394	5961	187000	1394000
74	42	68	41	0	68000	41000
75	43	80	701	1520	80000	701000
76	44	525	3773	9608	525000	3773000
77	45	65	658	1431	65000	658000
78	46	52	522	18503	52000	522000
79	2	589	6928	0	589000	6928000
80	4	766	7947	132298	766000	7947000
81	5	1349	20566	4950	1349000	20566000
82	7	731	5150	88581	731000	5150000
83	8	1116	14083	55536	1116000	14083000
84	9	985	1143	48526	985000	1143000
85	10	2117	6091	199719	2117000	6091000
86	11	3433	5399	17520	3433000	5399000

```
MTB > let c20 = sqrt(c4)
MTB > hist c4

Histogram of C4   N = 86

Midpoint   Count
       0      47  ***********************************************
   20000      13  *************
   40000       5  *****
   60000       3  ***
   80000       6  ******
  100000       4  ****
  120000       2  **
  140000       2  **
  160000       1  *
  180000       1  *
  200000       2  **
```

```
MTB > hist c20

Histogram of C20   N = 86

Midpoint   Count
       0      18  ******************
      50      21  *********************
     100      13  *************
     150       8  ********
     200       5  *****
     250       6  ******
     300       7  *******
     350       3  ***
     400       2  **
     450       3  ***

MTB > regr c4 1 c5

The regression equation is
C4 = 24212 + 0.0207 C5

Predictor         Coef           Stdev      t-ratio
Constant         24212            7139         3.39
C5             0.02068         0.01001         2.06

s = 49579        R-sq = 4.8%      R-sq(adj) = 3.7%

Analysis of Variance

SOURCE         DF            SS            MS
Regression      1   10478141440   10478141440
Error          84  206479884288    2458093824
Total          85  216957976576

Unusual Observations
Obs.        C5         C4          Fit  Stdev.Fit   Residual    St.Resid
  9     234000     162001        29050       5855     132951       2.70R
 14    1869000      12568        62857      14974     -50289      -1.06 X
 45     374000     188610        31945       5436     156665       3.18R
 71      93000     204700        26135       6559     178565       3.63R
 85    2117000     199719        67984      17316     131735       2.84RX
 86    3433000      17520        95195      30128     -77675      -1.97 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c20 1 c5

The regression equation is
C20 = 107 +0.000058 C5

Predictor         Coef           Stdev      t-ratio
Constant        106.93           17.81         6.00
C5          0.00005824      0.00002498         2.33

s = 123.7        R-sq = 6.1%      R-sq(adj) = 5.0%

Analysis of Variance

SOURCE         DF            SS            MS
Regression      1         83125         83125
Error          84       1284803         15295
Total          85       1367927
```

```
Unusual Observations
Obs.       C5        C20        Fit  Stdev.Fit  Residual    St.Resid
  9    234000      402.5      120.6       14.6     281.9       2.30R
 14   1869000      112.1      215.8       37.4    -103.7      -0.88 X
 45    374000      434.3      128.7       13.6     305.6       2.49R
 71     93000      452.4      112.3       16.4     340.1       2.77R
 85   2117000      446.9      230.2       43.2     216.7       1.87 X
 86   3433000      132.4      306.9       75.2    -174.5      -1.78 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c4 1 c6

The regression equation is
C4 = 30614 + 0.00084 C6

Predictor       Coef          Stdev      t-ratio
Constant       30614           7204         4.25
C6          0.000844       0.001177         0.72

s = 50667       R-sq = 0.6%       R-sq(adj) = 0.0%

Analysis of Variance

SOURCE         DF           SS           MS
Regression      1   1318367744   1318367744
Error          84 215639654400   2567138560
Total          85 216957976576

Unusual Observations
Obs.       C6         C4        Fit  Stdev.Fit  Residual    St.Resid
  8  31788992          0      57433      33182    -57433      -1.50 X
  9   3664000     162001      33705       5477    128296       2.55R
 45   2835000     188610      33006       5630    155604       3.09R
 67   2634000     146034      32836       5692    113198       2.25R
 71    712000     204700      31215       6688    173485       3.45R
 81  20566000       4950      47965      20267    -43015      -0.93 X
 85   6091000     199719      35753       5998    163966       3.26R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c20 1 c6

The regression equation is
C20 = 127 +0.000002 C6

Predictor       Coef          Stdev      t-ratio
Constant      127.42          18.11         7.04
C6        0.00000176     0.00000296         0.59

s = 127.3       R-sq = 0.4%       R-sq(adj) = 0.0%

Analysis of Variance

SOURCE         DF           SS           MS
Regression      1         5730         5730
Error          84      1362198        16217
Total          85      1367928
```

```
Unusual Observations
Obs.       C6        C20         Fit  Stdev.Fit   Residual    St.Resid
  8 31788992         0.0       183.3       83.4     -183.3     -1.91 X
  9  3664000       402.5       133.9       13.8      268.6      2.12R
 45  2835000       434.3       132.4       14.1      301.9      2.39R
 71   712000       452.4       128.7       16.8      323.8      2.56R
 81 20566000        70.4       163.6       50.9      -93.2     -0.80 X
 85  6091000       446.9       138.1       15.1      308.8      2.44R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > hist c5

Histogram of C5   N = 86

Midpoint   Count
       0      34  **********************************
  400000      32  ********************************
  800000       8  ********
 1200000       8  ********
 1600000       1  *
 2000000       2  **
 2400000       0
 2800000       0
 3200000       0
 3600000       1  *

MTB > hist c6

Histogram of C6   N = 86

 Midpoint   Count
        0      36  ************************************
  4000000      32  ********************************
  8000000      13  *************
 12000000       2  **
 16000000       1  *
 20000000       1  *
 24000000       0
 28000000       0
 32000000       1  *

MTB > let c21 = logt(c5)
MTB > hist c21

Histogram of C21   N = 86

Midpoint   Count
     3.6       2  **
     4.0       2  **
     4.4       2  **
     4.8      13  *************
     5.2      18  ******************
     5.6      30  ******************************
     6.0      16  ****************
     6.4       3  ***
```

```
MTB > let c22 = sqrt(c6)
MTB > hist c22

Histogram of C22   N = 86

Midpoint   Count
       0       2  **
     500       9  *********
    1000      18  ******************
    1500      15  ***************
    2000      18  ******************
    2500      12  ************
    3000       7  *******
    3500       2  **
    4000       1  *
    4500       1  *
    5000       0
    5500       1  *

MTB > regr c4 1 c21

The regression equation is
C4 = - 57772 + 16979 C21

Predictor        Coef          Stdev     t-ratio
Constant       -57772          51989       -1.11
C21             16979           9569        1.77

s = 49895       R-sq = 3.6%      R-sq(adj) = 2.5%

Analysis of Variance

SOURCE         DF           SS             MS
Regression      1   7837642752     7837642752
Error          84 209120395264     2489528320
Total          85 216957976576

Unusual Observations
Obs.      C21         C4         Fit  Stdev.Fit   Residual    St.Resid
  5      4.11     100000       12079      13465      87921      1.83 X
  9      5.37     162001       33392       5390     128609      2.59R
 16      3.60       3079        3387      18061       -308     -0.01 X
 23      3.60      73154        3387      18061      69767      1.50 X
 39      4.15      25500       12625      13183      12875      0.27 X
 45      5.57     188610       36850       5618     151760      3.06R
 67      6.17     146034       47062       9128      98972      2.02R
 71      4.97     204700       26588       6804     178112      3.60R
 85      6.33     199719       49632      10333     150087      3.07R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c20 1 c21

The regression equation is
C20 = - 120 + 47.1 C21

Predictor        Coef          Stdev     t-ratio
Constant       -120.0          130.0       -0.92
C21             47.09          23.93        1.97

s = 124.8       R-sq = 4.4%      R-sq(adj) = 3.3%

Analysis of Variance

SOURCE         DF           SS             MS
Regression      1        60280          60280
Error          84      1307648          15567
Total          85      1367928
```

Unusual Observations

Obs.	C21	C20	Fit	Stdev.Fit	Residual	St.Resid
5	4.11	316.2	73.7	33.7	242.5	2.02RX
9	5.37	402.5	132.8	13.5	269.7	2.17R
16	3.60	55.5	49.6	45.2	5.9	0.05 X
23	3.60	270.5	49.6	45.2	220.9	1.90 X
39	4.15	159.7	75.2	33.0	84.5	0.70 X
45	5.57	434.3	142.4	14.0	291.9	2.35R
71	4.97	452.4	113.9	17.0	338.5	2.74R
85	6.33	446.9	177.8	25.8	269.1	2.20R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c4 1 c22

The regression equation is
C4 = 18256 + 9.01 C22

Predictor	Coef	Stdev	t-ratio
Constant	18256	11078	1.65
C22	9.015	5.547	1.63

s = 50041 R-sq = 3.0% R-sq(adj) = 1.9%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	1	6613970944	6613970944
Error	84	210344083456	2504096000
Total	85	216958042112	

Unusual Observations

Obs.	C22	C4	Fit	Stdev.Fit	Residual	St.Resid
8	5638	0	69082	22263	-69082	-1.54 X
9	1914	162001	35511	5478	126490	2.54R
45	1684	188610	33434	5406	155176	3.12R
67	1623	146034	32886	5438	113148	2.27R
71	844	204700	25862	7352	178838	3.61R
81	4535	4950	59137	16394	-54187	-1.15 X
85	2468	199719	40504	6726	159215	3.21R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c20 1 c22

The regression equation is
C20 = 93.3 + 0.0236 C22

Predictor	Coef	Stdev	t-ratio
Constant	93.33	27.78	3.36
C22	0.02357	0.01391	1.69

s = 125.5 R-sq = 3.3% R-sq(adj) = 2.2%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	1	45206	45206
Error	84	1322722	15747
Total	85	1367928	

Unusual Observations

Obs.	C22	C20	Fit	Stdev.Fit	Residual	St.Resid
8	5638	0.0	226.2	55.8	-226.2	-2.01RX
9	1914	402.5	138.4	13.7	264.1	2.12R
45	1684	434.3	133.0	13.6	301.3	2.42R
67	1623	382.1	131.6	13.6	250.6	2.01R
71	844	452.4	113.2	18.4	339.2	2.73R
81	4535	70.4	200.2	41.1	-129.9	-1.10 X
85	2468	446.9	151.5	16.9	295.4	2.38R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c20 2 c5 c22

The regression equation is
C20 = 92.8 +0.000049 C5 + 0.0106 C22

Predictor	Coef	Stdev	t-ratio
Constant	92.84	27.47	3.38
C5	0.00004890	0.00002863	1.71
C22	0.01060	0.01571	0.67

s = 124.1 R-sq = 6.6% R-sq(adj) = 4.3%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	2	90137	45069
Error	83	1277790	15395
Total	85	1367927	

SOURCE	DF	SEQ SS
C5	1	83125
C22	1	7013

Unusual Observations

Obs.	C5	C20	Fit	Stdev.Fit	Residual	St.Resid
8	364000	0.0	170.4	64.1	-170.4	-1.60 X
9	234000	402.5	124.6	15.8	277.9	2.26R
45	374000	434.3	129.0	13.6	305.3	2.48R
71	93000	452.4	106.3	18.7	346.1	2.82R
81	1349000	70.4	206.9	40.8	-136.5	-1.17 X
85	2117000	446.9	222.5	44.8	224.4	1.94 X
86	3433000	132.4	285.4	81.8	-153.0	-1.64 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > plot c4 c5

```
          -
          -
  210000+ * #71
          -                               *
  C4      -   * #45
          -  * #9
          -
  140000+                          *
          -             *    *
          -       *
          - *      2 *
          -      *   * *
   70000+ *       * **  *
          -                 *
          -       * *     **
          - 2 * *
          - *22 *5 * **          *                    * #86
       0+ 2+643*3*22    2 * 2
          +---------+---------+---------+---------+---------+------ C5
          0      700000   1400000   2100000   2800000   3500000
```

```
MTB > plot c4 c6

             -
             -
   210000+  *
             -         *
  C4         -    *
             -     *
             -
   140000+    *
             -          2
             -   *
             -      **    2
             -         **   *
    70000+   2      *       *      *
             -                        *
             -   *    ** *
             -  * 2*
             - *2*****232    *
        0+ 6955**2*2*****  *      *            *  #81          * #8
             +---------+---------+---------+---------+---------+------C6
             0     6000000  12000000  18000000  24000000  30000000

MTB > delete 86 c1-c6
MTB > delete 81 c1-c6
MTB > delete 71 c1-c6
MTB > delete 45 c1-c6
MTB > delete 9 c1-c6
MTB > delete 8 c1-c6
MTB > print c1-c6
```

ROW	C1	C2	C3	C4	C5	C6
1	1	95	48	0	95000	48000
2	2	116	584	3520	116000	584000
3	3	250	6210	0	250000	6210000
4	4	166	3180	0	166000	3180000
5	5	13	3524	100000	13000	3524000
6	6	412	6882	100000	412000	6882000
7	7	26	320	30800	26000	320000
8	10	551	7726	89608	551000	7726000
9	11	190	2066	4693	190000	2066000
10	12	488	5451	40826	488000	5451000
11	13	177	1386	17240	177000	1386000
12	14	1869	7984	12568	1869000	7984000
13	15	261	2496	0	261000	2496000
14	16	4	120	3079	4000	120000
15	17	415	4604	9331	415000	4604000
16	18	421	2860	20327	421000	2860000
17	19	861	12264	74980	861000	12264000
18	20	417	3607	1007	417000	3607000
19	21	150	1908	25684	150000	1908000
20	22	26	153	1615	26000	153000
21	23	4	967	73154	4000	967000
22	24	289	4935	5453	289000	4935000
23	25	1141	8001	123555	1141000	8001000
24	26	421	1737	5159	421000	1737000
25	27	198	847	2757	198000	847000
26	28	84	619	2441	84000	619000
27	29	409	4567	8913	409000	4567000
28	30	107	854	19714	107000	854000
29	31	159	87	0	159000	87000
30	32	472	1295	63558	472000	1295000
31	33	108	133	2160	108000	133000
32	34	192	161	7200	192000	161000
33	1	1166	1308	4380	1166000	1308000
34	2	403	3470	0	403000	3470000
35	3	1030	1745	5389	1030000	1745000

36	5	1050	13236	0	1050000	13236000
37	6	14	2426	25500	14000	2426000
38	7	391	5454	12191	391000	5454000
39	8	578	7690	67519	578000	7690000
40	9	636	8833	0	636000	8833000
41	10	147	1945	0	147000	1945000
42	11	352	1774	115896	352000	1774000
43	13	561	5158	0	561000	5158000
44	14	48	398	0	48000	398000
45	15	723	4300	13498	723000	4300000
46	16	1354	7644	3720	1354000	7644000
47	17	65	957	0	65000	957000
48	18	368	3575	74675	368000	3575000
49	19	361	3925	8528	361000	3925000
50	20	427	2107	11180	427000	2107000
51	21	763	4613	15611	763000	4613000
52	22	313	5788	88962	313000	5788000
53	23	352	3699	41016	352000	3699000
54	24	447	4075	101121	447000	4075000
55	25	580	6692	93000	580000	6692000
56	26	104	6556	0	104000	6556000
57	27	70	1008	0	70000	1008000
58	28	73	977	2911	73000	977000
59	29	1082	3905	45669	1082000	3905000
60	30	312	1669	27676	312000	1669000
61	31	111	651	4450	111000	651000
62	32	494	4666	623	494000	4666000
63	33	77	791	6551	77000	791000
64	34	1494	2634	146034	1494000	2634000
65	35	61	511	3048	61000	511000
66	36	626	4203	5488	626000	4203000
67	37	157	1591	7373	157000	1591000
68	39	213	2066	1370	213000	2066000
69	41	187	1394	5961	187000	1394000
70	42	68	41	0	68000	41000
71	43	80	701	1520	80000	701000
72	44	525	3773	9608	525000	3773000
73	45	65	658	1431	65000	658000
74	46	52	522	18503	52000	522000
75	2	589	6928	0	589000	6928000
76	4	766	7947	132298	766000	7947000
77	7	731	5150	88581	731000	5150000
78	8	1116	14083	55536	1116000	14083000
79	9	985	1143	48526	985000	1143000
80	10	2117	6091	199719	2117000	6091000

```
MTB > hist c4

Histogram of C4   N = 80

Midpoint    Count
       0       45  *********************************************
   20000       12  ************
   40000        5  *****
   60000        3  ***
   80000        6  ******
  100000        4  ****
  120000        2  **
  140000        2  **
  160000        0
  180000        0
  200000        1  *
```

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```
MTB > let c30 = sqrt(c4)
MTB > hist c30

Histogram of C30   N = 80

Midpoint   Count
       0      17  *****************
      50      20  ********************
     100      13  *************
     150       7  *******
     200       5  *****
     250       6  ******
     300       7  *******
     350       3  ***
     400       1  *
     450       1  *

MTB > regr c4 1 c5

The regression equation is
C4 = 9302 + 0.0460 C5

Predictor        Coef          Stdev     t-ratio
Constant         9302           6053        1.54
C5           0.046016       0.009926        4.64

s = 37977        R-sq = 21.6%     R-sq(adj) = 20.6%

Analysis of Variance

SOURCE       DF            SS            MS
Regression    1   30999834624   30999834624
Error        78  112496345088    1442260736
Total        79  143496118272


Unusual Observations
Obs.      C5          C4        Fit  Stdev.Fit   Residual    St.Resid
  5    13000      100000       9900       5962      90100       2.40R
 12  1869000       12568      95306      14856     -82738      -2.37RX
 42   352000      115896      25499       4325      90396       2.40R
 64  1494000      146034      78050      11339      67984       1.88 X
 76   766000      132298      44550       5370      87748       2.33R
 80  2117000      199719     106718      17229      93000       2.75RX

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c30 1 c5

The regression equation is
C30 = 76.5 +0.000114 C5

Predictor        Coef          Stdev     t-ratio
Constant        76.48          17.01        4.50
C5         0.00011362     0.00002789        4.07

s = 106.7        R-sq = 17.5%     R-sq(adj) = 16.5%

Analysis of Variance

SOURCE       DF            SS            MS
Regression    1        188978        188978
Error        78        888001         11385
Total        79       1076978
```

Unusual Observations

Obs.	C5	C30	Fit	Stdev.Fit	Residual	St.Resid
5	13000	316.2	78.0	16.8	238.3	2.26R
12	1869000	112.1	288.8	41.7	-176.7	-1.80 X
42	352000	340.4	116.5	12.2	224.0	2.11R
64	1494000	382.1	246.2	31.9	135.9	1.33 X
80	2117000	446.9	317.0	48.4	129.9	1.37 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

```
MTB > regr c4 1 c6
```

The regression equation is
C4 = 13045 + 0.00468 C6

Predictor	Coef	Stdev	t-ratio
Constant	13045	6767	1.93
C6	0.004678	0.001453	3.22

s = 40297   R-sq = 11.7%   R-sq(adj) = 10.6%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	1	16838246400	16838246400
Error	78	126657953792	1623819776
Total	79	143496183808	

Unusual Observations

Obs.	C6	C4	Fit	Stdev.Fit	Residual	St.Resid
17	12264000	74980	70420	13539	4560	0.12 X
36	13236000	0	74967	14878	-74967	-2.00RX
42	1774000	115896	21345	5139	94551	2.37R
64	2634000	146034	25368	4668	120666	3.01R
76	7947000	132298	50224	7905	82074	2.08R
78	14083000	55536	78929	16056	-23393	-0.63 X
80	6091000	199719	41541	5894	158178	3.97R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

```
MTB > regr c30 1 c6
```

The regression equation is
C30 = 84.4 +0.000012 C6

Predictor	Coef	Stdev	t-ratio
Constant	84.38	18.70	4.51
C6	0.00001194	0.00000401	2.97

s = 111.4   R-sq = 10.2%   R-sq(adj) = 9.0%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	1	109626	109626
Error	78	967352	12402
Total	79	1076978	

```
Unusual Observations
Obs.       C6        C30         Fit  Stdev.Fit  Residual    St.Resid
 17 12264000       273.8       230.8       37.4      43.0      0.41 X
 36 13236000         0.0       242.4       41.1    -242.4     -2.34RX
 42  1774000       340.4       105.6       14.2     234.9      2.13R
 64  2634000       382.1       115.8       12.9     266.3      2.41R
 78 14083000       235.7       252.5       44.4     -16.8     -0.16 X
 80  6091000       446.9       157.1       16.3     289.8      2.63R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > hist c5

Histogram of C5   N = 80

Midpoint    Count
       0       18  ******************
  200000       19  *******************
  400000       19  *******************
  600000        8  ********
  800000        5  *****
 1000000        4  ****
 1200000        3  ***
 1400000        2  **
 1600000        0
 1800000        1  *
 2000000        0
 2200000        1  *

MTB > hist c6

Histogram of C6   N = 80

 Midpoint    Count
        0       22  **********************
  2000000       20  ********************
  4000000       17  *****************
  6000000       11  ***********
  8000000        7  *******
 10000000        0
 12000000        1  *
 14000000        2  **


MTB > let c31 =logt(c5)
MTB > hist c31

Histogram of C31   N = 80

Midpoint    Count
     3.6        2  **
     3.8        0
     4.0        0
     4.2        2  **
     4.4        2  **
     4.6        1  *
     4.8        8  ********
     5.0        8  ********
     5.2       10  **********
     5.4        6  ******
     5.6       17  *****************
     5.8       12  ************
     6.0        8  ********
     6.2        3  ***
     6.4        1  *
```

```
MTB > let c32 = sqrt(c6)
MTB > hist c32

Histogram of C32   N = 80

Midpoint   Count
       0       2  **
     500       9  *********
    1000      17  *****************
    1500      14  **************
    2000      17  *****************
    2500      11  ***********
    3000       7  *******
    3500       2  **
    4000       1  *

MTB > regr c4 1 c31

The regression equation is
C4 = - 88913 + 21964 C31

Predictor        Coef          Stdev     t-ratio
Constant       -88913          44333       -2.01
C31             21964           8192        2.68

s = 41042        R-sq = 8.4%      R-sq(adj) = 7.3%

Analysis of Variance

SOURCE        DF            SS            MS
Regression     1   12107689984   12107689984
Error         78  131388473344    1684467456
Total         79  143496118272


Unusual Observations
Obs.      C31          C4         Fit  Stdev.Fit   Residual    St.Resid
  5      4.11      100000        1445      11359      98554      2.50RX
 14      3.60        3079       -9798      15290      12877      0.34 X
 21      3.60       73154       -9798      15290      82951      2.18RX
 42      5.55      115896       32911       4782      82985      2.04R
 64      6.17      146034       46700       7947      99334      2.47R
 76      5.88      132298       40328       6161      91970      2.27R
 80      6.33      199719       50025       8988     149694      3.74R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c30 1 c31

The regression equation is
C30 = - 181 + 57.1 C31

Predictor        Coef          Stdev     t-ratio
Constant       -181.3          122.0       -1.49
C31             57.08          22.55        2.53

s = 113.0        R-sq = 7.6%      R-sq(adj) = 6.4%

Analysis of Variance

SOURCE        DF            SS            MS
Regression     1         81764         81764
Error         78        995215         12759
Total         79       1076978
```

```
Unusual Observations
Obs.     C31        C30        Fit  Stdev.Fit   Residual    St.Resid
  5     4.11      316.2       53.5       31.3      262.8      2.42RX
 14     3.60       55.5       24.3       42.1       31.2      0.30 X
 21     3.60      270.5       24.3       42.1      246.2      2.35RX
 80     6.33      446.9      179.7       24.7      267.2      2.42R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.


MTB > regr c4 1 c32

The regression equation is
C4 = - 1993 + 18.8 C32

Predictor         Coef          Stdev     t-ratio
Constant         -1993           9845       -0.20
C32             18.817          5.281        3.56

s = 39776        R-sq = 14.0%     R-sq(adj) = 12.9%

Analysis of Variance

SOURCE         DF            SS            MS
Regression      1   20089384960   20089384960
Error          78  123406778368    1582138112
Total          79  143496118272

Unusual Observations
Obs.     C32         C4        Fit  Stdev.Fit   Residual    St.Resid
 36     3638          0      66467      11338     -66467     -1.74 X
 42     1332     115896      23070       4779      92826      2.35R
 64     1623     146034      28547       4452     117487      2.97R
 76     2819     132298      51054       7552      81244      2.08R
 78     3753      55536      68624      11897     -13088     -0.34 X
 80     2468     199719      44448       6151     155271      3.95R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regr c30 1 c32

The regression equation is
C30 = 43.0 + 0.0498 C32

Predictor         Coef          Stdev     t-ratio
Constant         43.05          27.12        1.59
C32            0.04980        0.01455        3.42

s = 109.6        R-sq = 13.1%     R-sq(adj) = 11.9%

Analysis of Variance

SOURCE         DF            SS            MS
Regression      1        140675        140675
Error          78        936304         12004
Total          79       1076978


Unusual Observations
Obs.     C32        C30        Fit  Stdev.Fit   Residual    St.Resid
 36     3638        0.0      224.2       31.2     -224.2     -2.13RX
 42     1332      340.4      109.4       13.2      231.1      2.12R
 64     1623      382.1      123.9       12.3      258.3      2.37R
 78     3753      235.7      229.9       32.8        5.7      0.05 X
 80     2468      446.9      165.9       16.9      281.0      2.60R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.
```

MTB > regr c4 2 c5 c32

The regression equation is
C4 = 688 + 0.0372 C5 + 7.49 C32

Predictor	Coef	Stdev	t-ratio
Constant	688	9417	0.07
C5	0.03717	0.01237	3.00
C32	7.491	6.285	1.19

s = 37875 R-sq = 23.0% R-sq(adj) = 21.0%

Analysis of Variance

SOURCE	DF	SS	MS
Regression	2	33037799424	16518897664
Error	77	110458372096	1434524160
Total	79	143496118272	

SOURCE	DF	SEQ SS
C5	1	30999834624
C32	1	2037964800

Unusual Observations

Obs.	C5	C4	Fit	Stdev.Fit	Residual	St.Resid
5	13000	100000	15233	7442	84767	2.28R
12	1869000	12568	91326	15188	-78758	-2.27RX
42	352000	115896	23749	4556	92147	2.45R
64	1494000	146034	68378	13919	77656	2.20RX
76	766000	132298	50278	7196	82020	2.21R
80	2117000	199719	97865	18720	101854	3.09RX

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > plot c4 c5

```
        -                                                      *
        -
  180000+
        -
C4      -
        -                                      *
        -                    *
  120000+          *                   *
        -
        - *         **   *
        -         *     *   *
        - *        *    *       *
   60000+            *               *
        -                          * *
        -  *       *  *
        - ** **    *  *
        -   * 2*   *3* *    **                           *
       0+ *29434*2  2** **2         2  *    *
          +---------+---------+---------+---------+---------+------C5
          0    400000    800000   1200000   1600000   2000000
```

```
MTB > plot c4 c6
        -                     *
        -
  180000+
        -
C4      -
        -          *
        -                           *
  120000+       *                    *
        -
        -             * *       **
        -                  * *      *
        -    *        *             *              *     *
   60000+     *                                          *
        -     *        *
        -  *          *     *
        -   **  2 * *
        -  * * 2 *     2*3  *        *
       0+ 5264**32*  *2 * 2*    *** *   *              *
          +---------+---------+---------+---------+---------+---------+------C6
          0   3000000   6000000   9000000  12000000  15000000
```

APPENDIX G

CHART OF COMPLEXITY

project type	0	0- $10,000	$10,000- $50,000	$50,000- $100,000	$100,000- $500,000	$500,000 & above
	Ranges					
NOT COMPLEX						
# of projects in range	6	11	9	5	3	0
% of # in range to total NC projects	17.7	32.4	26.5	14.7	8.8	0
% of NC projects to total in range	35.3	35.3	42.3	41.7	30.0	0
COMPLEX						
# of projects in range	10	14	12	4	5	1
% of # in range to total C projects	21.7	30.4	26.1	8.7	10.9	2.2
% of C projects to total in range	58.8	53.9	50.0	33.3	50.0	50.0
VERY COMPLEX						
# of projects in range	1	1	3	3	2	1
% of # in range to total VC projects	9.1	9.1	27.3	27.3	18.2	9.1
% of VC projects to total in range	5.9	3.8	12.5	25.0	20.0	50.0
total # of projects in range	17	26	24	12	10	2
% of # in range to all 91 projects	18.7	28.6	26.4	13.2	11.0	2.2

	% of total (1)	% with A/E liability (2)	% with A/E liability of total 1x2
NC	34/91 = 37.3%	28/34 = 82.3%	30.7
C	46/91 = 50.6%	36/46 = 78.3%	39.6
VC	11/91 = 12.1%	10/11 = 90.9%	11.0

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